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GENERAL PRESIDENT: DR. D. M. BOSE, M.A.,Ph.D.,F.N.I.

Presidential Address

THE LIVING AND THE NON-LIVING

As the subject for my address for to-day I have selected the title "The living and the non-living". Fifty years ago in 1902 Acharya Jagadish Chandra Bose published a monograph on "Responses in the Living and in the Non-living" The book, because of the pantheistic nature of the conclusions arrived at aroused considerable interest amongst a large section of our educated public. Taking as the criterion of livingness, electric response to stimulation, Acharya Jagadish Chandra showed that under analogous conditions similar electric responses could be obtained by stimulation, both from living and non-living specimens. The starting point of these investigations was Bose's experiments with electric waves. The detector of electric waves in his apparatus was called coherer, whose resistance was reversibly reduced under the impact of electric radiation, and it could be detected by a deflection of the galvanometer connected with the coherer. Even in 1896 Bose was a biophysicist —he called the coherer the electric eye, the connecting wire the optic nerve and the galvanometer the brain. This biological analogy struck him when he found that his coherer suffered from fatigue and recovered when given sufficient rest. He devised many other models of the eye, of which the following one approximated best to an actual eye, a hollowed silver cup whose inner side was exposed to bromine vapour and filled with distilled water. This model eye also produced on illumination a galvanometer deflection. Two conclusions were drawn by him from these experiments **(i) that no demarcation line could be drawn which separated the physiological from the physical process—the physiological is an expression of the physico-chemical and (ii) responsive processes in life were preshadowed in non-life and there was no abrupt break but a continuity of law.**[5b] This was the first attempt ever made to subsume under common physiological laws, response to stimulation in living and non living systems. I will not speak here of his later investigations on the unity of life processes in plants and animals,[5c] which I have discussed in a recent monograph[4a].

Fifty years elapsed before a fresh synthesis was attempted, to describe the principles of communication and control in living and non-living organisms under common physiological laws. During the end of this period, coinciding with the last war, many complicated machines, using electron tube switching and amplifying devices, were constructed which could perform intricate tasks on receipt of instructions and messages from outisde e.g., (i) computing machines to solve numerically intricate differential equations which had been supplied as data (ii) detection of enemy airplane by means of radar and the training of guns on the planes. As a side result of the invention of many echo ranging devices used for war purposes, it was discovered that many animals had been using such signalling devices. The time therefore seemed ripe to formulate a new discipline

which described under common physiological laws, communication and control in animals and machines, for which the name Cybernetics was coined[23].

Our knowledge of the evolution both in the organic and in the inorganic worlds and the inter relation between the two has advanced considerably during the last fifty years. The relation between the living and the non-living has been made the subject of many important studies by competent investigators in many branches of science. I have thought it worthwhile to present a review of some aspects of this subject which has interested me for some time

The only form of life known to us is what has appeared on this earth. We do not know whether life has appeared in other parts of the Universe, under conditions similar to or different from those prevailing on this earth. The fitness of the environment for the appearance of life here dependend partly on the chemical properties of the elements, which in various combinations contribute the material structure of the living organism, and partly on the physical conditions which favoured the formation of complex molecules out of which the life process began. This possibility along with many others were implicit at the period when the present phase of evolution of the universe commenced, coinciding with the creation of chemical elements in their relative abundance out of lighter atoms, possibly hydrogen. The history of evolution of living organisms therefore dates back right to the beginnings of the universe, and can be for our purpose roughly divided into three periods; the first one from the origin of the universe to the formation of the worlds, in particular of the earth, with its profusion of chemical species. The second period is concerned with the transition from the non-living to the living. The third period is concerned with the evolution of living organisms and stretches upto the present time. I shall deal principally with the characteristics of living organisms as autonomous energy systems, maintaining themselves by means of a continuous interchange of matter and energy with the environment. After presenting some related observational data, I shall discuss how far the activities of the living organism is interpretable interms of known laws of physics and chemistry viz., as an autonomous energy system. In the opinion of many competent biologists, it becomes necessary at some phase in the development of the organism to take into consideration new factors, one of which became emergent when the transition from the non-living to the living took place, and the other with the emergence of the mind as a factor in partly controlling the activities of the organism; along with it there arises the further question whether the process by which the organism gets adapted to changes in its environment is explicable as due only to natural selection operating on the results of chance variations in the hereditary mechanism of the organisms, or whether additional directive factors operate.

Cosmology.—If we look to the evolution of cosmological theories, we notice the appearance in succession of two alternative theories of finite and infinite universe. From the time of Ptolemy to the medieval ages, the universe was taken to be finite in dimension and according to Christian theology of finite duration. Since the time of Newton, the world was conceived as infinite both in space and in time.

Recently a great deal of evidence has accumulated which tend to show that the universe had a beginning in time, which is approximately taken to be about five billion (5×10^9) years, and that it has finite though

rapidly expanding dimensions. Further the component parts including the earth and its heavy radioactive elements like uranium, were formed at about the same time. This epoch of creation of matter can be calculated from radioctive data, and agrees in order of magnitude with other estimates of the age of the universe. The conclusion that the universe is expanding is drawn from spectroscopic evidence, which shows that the constituent galaxies of the universe have velocities of recession which increases with their distances. The boundary of such a universe lies in the region where the receeding galaxies have attained the velocity of light, and from where therefore no light signals can reach us.

In such a universe the average density of matter will diminish with time. All temperature differences will disappear, the entropy will reach a maximum and the universe will attain the state of heat death.

In a recent alternate interpretation of an expanding universe, which is not running down, is associated with the names of Jordan, Bondi, and Gold. It is assumed that the universe is not finite, but infinite in extent and had existed from an infinite past and will continue indefinitely. Due to recessional velocities, some of the galaxies go out of the boundary of our observable universe. But at the same time continuous creation of matter, as hydrogen, is taking place from which new galaxies are being formed, so that the large scale appearance of the universe does not change with time—it is in a stationary state. The running down of the universe, because of the increase of it its entropy to a maximum is thus avoided. Although entropy increases in localised regions, the galaxies which pass out beyond the observational horizon carry entropy out of the observable universe. Consequently the entropy does not increase with time—the mean density of matter in the universe also remains constant for all time. The theory assumes, in violation of conservation of matter and energy principle of physics, a continuous creation of matter, which amounts on calculation to the creation of one hydrogen atom per cubic yard every 300,000 years.(19) Evasion of the conservation of energy principle in any finite portion of the universe is much too small to be detected. If this theory is found to be a better interpretation of the observable universe, it may also throw some light on the problem of interaction between mind and body, whether there is any transfer of energy involved in the inter-action. How the truth or otherwise of the alternative cosmological theories can be verified from the continued existence of living organism on this earth for over half a billion years, has been discussed in Sir Edmund Whittaker's recent rather controversial Eddington Memorial Lecture.(23)

Leaving aside such speculations, we shall take as a working model of the evolution of the universe that proposed by Weizsacker(21) which has the usual attributes of a model that it correlates a large number of observations, at the same time it raises certain theoretical objections which are left unanswered. The basic assumptions of this model are (i) the laws of physics have remained unaltered since the beginning of the present phase of the expanding universe (ii) the universe is a closed system across whose boundary no flow of energy and matter can take place. According to the second law of thermodynamics it follows, that the changes taking place in this closed system will be of an irreversible character, accompanied by increase of entropy. The latter is accompanied by equalisation of all differences of temperature as well as of all electrical and chemical, and other potentials. The universe will ultimately reach a state of heat death where while the total energy remains unaltered, it is in a unavialable form. Boltz-

mann first identified the entropy of a system as a function of its statistical probability, so that with increase of entropy a system will pass from a less to a more probable state. I will illustrate with some examples : (i) if one of two vessels is filled with a gas and the other is empty, then on connecting the two, gas will be come equally distributed in the two vessels which is a more probable distribution of the gasmolecules and has also the larger entropy (ii) a vacuum space enclosed within perfectly reflecting walls and filled with monochromatic radiation, will represent a state of labile equilibrium. If now a particle of matter is introduced, which can absorb radiations of all frequencies, it will lead to an interchange of energy between matter and radiation, until the radiation assumes what is known as black body character, where the spectral distribution of energy is a function of temperature only. The temperature is given by that of the piece of absorbing material particle. This represents a state of maximum entropy, for a given distribution of energy between matter and radiation; (iii) if a saturated solution of sugar is taken, in temperature equilibrium with its surroundings and a minute sugar crystal is dropped into it—sugar will start crystallizing out of the solution. Taken by itself the separation of the solution in a crystalline solid and a liquid phase represents a state of greater differentiation and therefore of lower probability. At the same time heat has evolved during crystallization. This has led to a transference of heat from the solution to the surrounding medium, resulting in an increase of total entropy of the system, including the solution with its enclosure.

The hypothesis of the universe as formulated by Weizsacker is as follows: Some billions of years ago, all matter contained in the portion of the world we know was compressed in a narrow space. At that time the heavy nuclei came into being out of light nuclei, possibly out of hydrogen. Then matter flew apart and acattered through space in the form of more and more diffused gas. The fastest of the exploded particles will occupy the outermost portion of this expanding mass of gas.

Weizsacker has shown how from this diffuse expanding gas system forming the earliest stage of the universe, where most of the energy is concentrated in the kinetic energy of the materials particles, turbulent motion will arise. In such an infinite distribution of gas of uniform density the resultant gravitational attraction on any particle is zero. Chance concentration of matter occuring in any region will attract additional matter there, and an individual body comes into existence, resulting in the conversion of the gravitational potential energy of the condensing matter into radiation. Once formed the condensed units will not dissipate away again into a gaseous system, as energy will be required. Such partial systems formed in a cloud in turbulent motion will as a rule rotate from the beginning. Celestial bodies observed by means of powerful telescopes have been found to belong to the classes of clouds, rotatory forms and spheres. They represent the different stages in the evolution from the initially diffuse expanding mass of gas. The rotating celestial bodies are varied in degree of organisation from spiral nebulae to bodies like the globular sun with its planetary system; most of them have a well defined plane and veritical to it an axis of rotation. They show an increasing order of organization and as such they represent a transition from a greater to a lower degree of probability. As I have said before, in discussing the crystallization of sugar out of a saturated solution, such an increase in organization can occur, without violation of the 2nd law of thermodynamics, in a part of an isolated system, if it is accompanied by

the conversion cf some kind of potential energy, chemical, or gravitational, into heat radiation, thereby increasing the total entropy of the isolated system. We find in Nature that there is always transitions from poor undifferentiated distribution of matter, rich in energy, kinetic, as well as potential, which create new forms always accompanied by a final transformation of the energy released in the process, to low temperature thermal radiation. We shall find when we turn to our earth, that new species of chemical molecules, crystals minerals, etc., were formed releasing chemical potential energy into heat radiation.

As inhabitant of the earth we are most interested in the origin of the sun with its planets. This represents the most differentiated form in the evolution of stars. Round the sun we have the planets moving in orbits of various degree of a ellipticity, all of them more or less coplanar, and rotating in the same direction. At one time it was thought that the planets were formed out of the rotating disc of gas, which was thrown out of the rotating sun at some period of its evolution. But the chemical composition of the planet best known to us, the earth, is against this view. According to recent views, the earth is supposed to have grown out of accretion of dust particles, meteorities and planetoids. These bodies were cold, as they were as far from the sun as the earth is to-day. The earth's interior has a temperature of several thousands of degrees. The heat of the earth could feed on two sources of energy; in the beginning on the kinetic energy of the fragments that combined to form the earth; since then and until to-day on the nuclear energy of the radioactive elements contained in the rocks.

The age of the earth in taken to be about 3.35 billion years[2] and the age of the oldest sedimentery rocks 2 billion years, since when the temperature on the earth's surface has remained within fairly stable limits. During the first period of its history, the earth was in a semiliquid condition, convection of matter between the core and the surface took place, resulting in the formation of an inner core of high density, consisting most likely of iron and nickel, with a lighter outer crust. The great continents are of lighter substance than the floor of the ocean. Like floes of ice, the continents float on heavier materials underneath.

With the gradual cooling of the surface temperature, condensation of water took place forming the hydrosphere, together with an enveloping atmosphere of gases and vapours. The absorption of solar radiation by the surface layers of the earth, led to a circulation of matter and energy in the form of wind, rain, and ocean currents, and these have partially shaped the earth's surface to its present appearance. Utilisation of solar energy became possible with, appearance of green plants, and of the circulation of matter and energy, when animals which could fly or swim appeared. The sun and the earth form a coupled system.

The sun is still a hot mass of gas, consisting mainly of hydrogen, in whose interior extremely high values of temperature and pressure exist. A hypothesis, originally proposed by Weiszacker and worked out in details by Bethe, accounts for the continuous generation of heat in the interior of hot stars including the sun, as due to a thermonuclear reaction, in which four hydrogen atoms are converted into a helium nucleus; the resulting loss of mass is given out as thermal energy. The surface temperature of the sun, of the photosphere, is estimated to be about 6000°K. Annually about 1.3×10^{21} K calories of solar energy strikes the surface of the earth,

and except for transformation of only a small fraction into organic matter, the rest is re-emitted as heat radiation at temperature of about 287° K. The wave length of maximum energy in the solar spectrum is at about 0.48μ while that in the emitted radiation it is at 10μ— this gives an idea of the degradation of radiant energy which has taken place.

Transition from the non-living to the living.

When the temperature had sufficiently cooled complex chemical molecules were formed, water had condensed on the surface of the earth, and conditions were becoming favourable for life. The oldest sedimentary rocks are estimated to be 2 billions years old, and earliest fossil records of primitive algae and worms are estimated to be over 1.2 billion years old; by this time organisms which these fossils represent had already become highly complex. (2.p.157) We may therefore roughly estimate the time taken for the transition between the evolution of complex chemical species and the first definite evidence of life to be about half a billion year. Several "improbable" transitions must have taken place, possibly in succession, before even the most elementary forms of living organisms known to us could have evolved. Taking a green alga as the simplest type of an autotrophic organism, which can maintain itself by synthesizing its own food requirement from inorganic compounds plus solar energy, we find that the following component parts and functions are essential:

(i) synthesis of complex molecules like protein, which form the essential constituent of cell structures and of the enzymes

(ii) mechanism for mobilisation of free energy, on which all the activities of the cell depends

(iii) origin of photosynthesis

(iv) origin of genes in the cell nucleus on which the self replication of the cell depends

(v) origin of the cell which is the smallest unit of living organism known to us.

It is generally assumed that the first step in the evolution of life was taken when protein like molecules began to form out of less complex constituents. The first organism had severely limited synthetic ability, subsisting on a readily available menu of organic materials formed by non-vital processes.

This is known as the heterotroph hypothesis of the origin of life. We owe to Oparin the suggestion that the first living organism on this earh exhausted the supply of organic materials which were essential for the origin of first life. Thus spontaneous generation of life could not occur again because the requisite materials were no longer available. Horowitz extended the idea, assuming that there were present to begin with complex organic compounds—presumably formed in the process of chemical evolution—and the first organism utilized some of these compounds which they were unable to synthesize. When the initial supply of these materials was exhausted, the original organism perished. But in the meantime there had occured mutation, resulting in living forms that could carry out the synthesis of the essential complex compounds from simplier ones remaining in the environment. Further mutations provided additional steps in the synthesis until finally there were organisms which could synthesize

all of the necssary complex compounds. The intermediate mutant forms, unable to perform the complex synthesis, were eliminated by natural selection, as the intermediate substance were exhausted from the environment.

This brilliant hypothesis of Horowitz provides a model of how the earliest self propogating organisms feeding on simpler compounds functioned. In present day organisms, mitochondria provide the nearest analogue to the functioning of such living units. They are marcomolecules containing a large number of enzymes so carranged spatially that the substrate of one enzyme has been synthesized by its neighbour[9]. These mitochondria are self duplicating and mutable but cannot exist outside the cytoplasm. Similar to it are the viruses which in the simplest form occur as crystallizable nucleoprotein molecules similar to gene molecules. They are found endowed with the property of self replication. But such organisms can only thrive inside living cells and represent degenerate parasitic forms, between whom and the primitive self propagating units there can be no analogy

These self duplicating units can only flourish inside living cells. Whether the proto life molecules were provided with analogous nutrient medium is doubtful. In any case many hurdles had to be crossed, of nature not known to us, before the evolution of the present unit of life, the cell became possible. With these remarks I shall leave the topic of transition from the non-living to the living.

Characteristics of living organisms

As thermodynamic system—The evolution of the inorganic universe can be considered as a historical process in time, in which at every stage the past conditioned the present. Its irreversible nature follows from the second law of thermodynamics; all changes taking place are from states of less to more probable distribution of matter and energy, accompanied by increase of entropy. On the earth similar increase in order has taken place, accompanied by evolution of chemical species, minerals and rocks, in which potentialities have been transformed to forms. With the origin of life on this earth, chemical evolution has been supplemented by organic evolution. But the same process of differentiation and creation of new forms continues. The thermodynamic characteristics of the living organism are similar to those of the non-living. There is a circulation of matter and energy through such organisms; the source of energy is ultimately the radiation from the sun with which the organism is thus coupled. Unlike non-living terrestial bodies, in which solar energy is first transformed into heat energy, working between different temperatures, the living organism absorbs energy under almost isothermal conditions, the energy is received as free energy. The unit of living organism, the cell is a highly differentiated entity, enclosed by a semipermeable cell wall, and divided into a nucleus and a cytoplasm. The latter contains inclusions like plastids, mitochondria etc., each with an envelope of semi permeable walls. If the supply of free energy as nutrient is stopped, only tissue breakdown processes will continue, resulting in the death of the cell with break down of structure, semi permeability of the enclosing membranes, and increase of entropy. The inflow of free energy thus maintains the state of differentiation in the cell. In this sense living organisms feed on negative entropy, but in no case is there a violation of the laws of thermodynamics. Whether the maintenance of organisation in the living cell involves besides

known physical and chemical forces, some additional directive principle I shall discuss later.

The living organism is thus an autonomous energy system, which takes in energy of a suitable kind for the maintenance of its activities, for growth and reproduction. The supply of all this energy is based upon oxidiation of carbohydrates molecules, either synthesized by the organism or supplied to it from outside. Organisms which manufacture their food requirements from inorganic materials are called autotrophic. I shall for the present consider only autotrophic unicellular organisms. The mechanism of carbohydrate synthesis depends upon the reduction of CO_2 molecules and can be represented symbolically as $CO_2+2H_2A \rightarrow [CH_2O]+H_2O+2A$; here $H_2 A$ is the hydrogen donor and CO_2 the acceptor. The process being endoergic requires the supply of free energy.

Two different types CO_2 reduction have been observed in autotrophic micro organisms:

(i) photosynthesis, in which the hydrogen donor is water and the source of energy is light absorbed by chlorophyll molecules present in chloroplasts.

(ii) chemosynthesis which is found in certain types of bacteria, where the hydrogen donor is SH_2 and the energy is supplied by the reduction of SH_2 to sulphur.

There are other bacteria, which carry out the reduction of CO_2 by a variety of inorganic reactions, including the oxidation by O_2 of nitrites, sulphides, sulphur, and hydrogen. These examples of chemosynthesis are of great interest in elucidating the general mechanism of hydrogenation of CO_2. However by far the most important of these processes is photosynthesis.

All the other types of heterotrophic organisms are dependent ultimately on green chlorophyll containing plants for the supply of energy rich carbohydrates.

The first sugar produced during photosynthesis is hexose $(CH_2O)_6$ from which by polymerisation more complex carbohydrates, like starch and cellulose are formed.

The energy involved in synthesis, respectively oxidation of hexose can be represented as follows:

$$6\ CO_2+6H_2O \leftrightarrows (CH_2O)_6+6O_2+ 686\ \text{K cal/mol.}$$

when the reaction proceeds to the right it is endoergonic requiring a supply of 686 K cal/mol of energy, while if it goes to the left it is exoergonic requiring an equal amount of energy. It may be mentioned that the processes can be commenced or ended at any intermediate stage in the living organism. The catalytic mechanism which facilitates the reaction will be discussed later. The carbohydrates not only provide the source of energy for all cellular processes, but some of their products like cellulose, hemicellulose, lignin, pectin form the building materials for plant structures.

Energy utilization in living organisms—Two of the main functions of the energy released by oxidation of glucose, are the synthesis of other molecules of biological importance, and performance of work by muscular contraction. The biochemical reactions underlying them proceed by isothermal coupling of an energy spending (exoergonic) with an energy receiving

(endoergonic) process. In the corresponding non-living counterparts, energy is supply by heat flowing down temperature gradients. I cite two illustrative examples:

(i) In a chemical plant, like the one installed at Sindri, fixation of nitrogen is brought about by processes which require supply of energy, both for compression of atmospheric nitrogen as well as heat for synthesis of energy rich nitrogen compounds. For this purpose, in thermal stations fossil fuel coal is generally utilized, alternately electric powder from hydroelectric generators.

Generation of mechanical power can be both by thermal plants or by hydroelectricity. In the former heat is generated by combusion of fossil fuel produced by photosynthetic activity in past ages, in the latter, the head of water for power generation is based upon evaporation of water by sun's rays.

In green plants glucose is synthesized by utilization of absorbed solar energy and in all living systems oxidation of glucose is utilized for supply of energy. Both the process take place at nearly constant temperatures. Several soil microorganism like *Azotobacter*, *Rhizobium*, can fix nitrogen by isothermal processes, based upon oxidation of glucose. In the nodules of leguminous plants a hemoprotein similar to blood hemoglobin, occur, which can be reversably oxygenated and deoxygenated, and serves to supply oxygen to *Rhizobium*.

The energy liberated in oxidative processes may be transported to other units of the cell by at least two well investigated methods, of which the most important is by means of energy rich phosphate intermediates like adenosine triphosphate (ATP), phosphates of creatine and arginine. When one mole of ATP is decomposed to ADP+a phosphate ion, 10 K cal. of energy is set free. The free phosphate can combine with glucose to form glucose-1-phosphate with an energy of oxidation of 3 K calories. This compound is the starting point for polymerisation of hexose into cellulose and other polysaccharides. Other known instances of the use of ATP are in the formation of pepitide bonds in the synthesis of proteins from amino acids, the synthesis of fatty acids etc.

From each mole of completely oxidised glucose which release 864 k. cal., 36-50 energy rich phosphate bonds are set free, which can be utilized in the cell for many purposes. The completion of the cycle of operation includes the resynthesis of ATP from $ADP+PO_3$; the energy of reformation comes ultimately from oxidation of glucose. In animal tissues ATP, creatine phosphate, and arginine phosphates are found; in plant tissues other energy rich phosphate compounds have been found, but the modes of their action are not known.

Pathways of glucose breakdown—The following three processes are known, all of which follow a common path $(CH_2O)_6 \rightarrow \underset{\text{(pyruvic acid)}}{2C_3H_4O_3} + 2H_2$; their final transformations are as follows:

1. $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6\ H_2O + 686$ K cal. : aerobic oxidation

2. $C_6H_{12}O_6 \rightarrow \underset{\text{(alcohol)}}{2C_2H_5OH} + 2CO_2 + 50$ K cal. : fermentation

3. $C_6H_{12}O_6 \rightarrow \underset{\text{(lactic acid)}}{2CH_3CH(OH).\ COOH} + 36$ K cal. : glycolysis

With a sufficient supply of O_2 (i) is carried out in all organisms. Under restricted supply of oxygen (ii) and (iii) occur; (ii) in yeast and (iii) in muscles.

Muscular work: Having considered the chemical transformations accompanying breakdown of glucose coupled with synthesis of other compounds of biological importance inside the cell, I shall next consider the case of how glucose breakdown supplies energy for muscular contraction. The muscles I shall consider are vertebrate striated muscles. Contraction of such muscle is brought about by stimulation of the attached effector nerve. The propogation of nervous electric excitation is ultimately based upon chemical metabolism in the nerve cell with its thread like processes the auxons, and is accompanied by increased nerve tissue respiration. Acetylcholine (ACh) is associated with nerve transmission in many not clearly understood ways. When the nervous excitation passes across the nerve end plate junctions with muscle fibre, an appreciable quantity of ACh is liberated, followed by muscular contraction and the disappearance of ACh after some time. ACh directly introduced in a nerve free muscle causes muscular twitches (18, p. 608).

How the release of ACh starts the contraction of a skeletal muscle is not clearly understood. The muscle contains a reserve of glycogen, ATP and phosphocreatine. The first step in the chemical changes accompanying the contractile process is the release of phosphate ion from phosphocreatine. This starts the breadkown of glycogen; after a number of intermediate steps it results in the formation of lactic acid. A part of the acid is completely oxidised and the rest reformed into glycogen in the liver. Phosphocreatine is reformed by the transfer of a phosphate ion from ATP.

While the contraction of skeletal muscle is neurogenic i.e., due to nerve stimulation, the rythmic contractions of a vertebrate heart muscle is not dependent on any extraneous nerve stimulation, and is called myogenic. It has been recently shown by Burns[3] that the contraction of vertebrate heart muscles is dependent on ACh. While in nerurogenic muscle, ACh is released by a nerve impulse at endplate junction, a chemical process is responsible for the formation of ACh in the heart muscle which is destroyed at each contraction. As in skeletal muscles the contractile pulsations of the heart are maintained by glycogen breakdown and the ATP is the activating agent. In both cases the releasing agent is ACh, in one case by the action of a nerve current and the other by a chemical process.

Electric Organs—When an excitation from a nerve passes from the nerve end plate junction to the connected muscle, it elicits along with muscle contraction an electric disturbance which travels along the muscle from end to end. It is believed that electric organs found in certain fishes in Africa and South America arise from a degeneration of the muscle endplate. The development of electric organs has been followed in very young specimens of the *Torpedo* or electric ray, where the various stages in the transformation of a muscle to an electroplax has been observed. A similar origin of electroplaxes is assumed in fishes possessing electric organs like the *Electrophorous* (*Gymnotus*), the electric ray (*Torpedo*) and in others. These electroplaxes are arranged in columns which may contain upto 400 plates, several columns together from the electric organ. Each electroplax is connected individually to the brain centre which controls their discharge. When stimulated they discharge in series and can generate potentials upto 500

volts.[11] In fact each column is equivalent to a Galvani pile. As at the ends with the motor nerves, the electroplaxes release a considerable amount of ACh when stimulated. They are also rich in phospocreatine, which diminish in quantity with activity.

The point which I have tried to illustrate here is, that not only the metabolism of the organisms but also their motor and electrical activities are brought about by a correlated series of chemical changes in the related tissues, and in every instance almost identical chemical reactions are involved (18, p. 631).

Biological building blocks—The structure and functions of organisms are as we shall see built up from a limited number of chemical elements, which are combined into a limited group of simple coumpounds. The latter in turn serve as construction units of large molecules which again are the building blocks of organisms as varied as unicellular cells like alga to the highly differentiated mammals. While natural selection has played a dominant role in the evolution of living organisms, its influence on the evolution of chemical units is probably negligible. One consequence of the existence of a limited number of biological building units and their limited variability is, that chance variation of organisms on which natural selection acts can only take place within limited ranges.

The principal chemical elements which enter in the organisms in diminishing quantities are H, O, C, N, Ca, P, Cl, S, Mg., with some traces of other elements. I shall next list some of the intermediate molecules which enter as units in large molecules

(i) Hexose, pentose and other carbohydrate building units composed entirely of C, H and O.

(ii) Molecules which in addition contain N, like the ring structured purine and pyrimidine. The amino acids of which about 20 have been isolated and their structure determined, form the structural units out of which the proteins are built up, contain in addition sulphur.

(iii) The pyrrole ring structure which occur in units of four in many molecules concerned with the absorption of light in photosynthesis, in the transport of oxygen, like heme, cytochrome.

I shall next pass on to the consideration of some of the large molecules which serve as building units or have special functional properties in the metabolic processess. The most important of them are:–

Protein—Molecular weight of protein ranges at least as high as 676000, which correspond to about 50,000 amino acids; these are joined together by what are known as peptide bonds. If the twenty amino aicids were combined at random along polypeptide chains, millions of different kinds of proteins would be possible; but actually there are a relatively few types, indicating that certain restrictions are imposed. The proportion of amino acid groups varies widely among the different kind of proteins, but there is evidence that a given amino acid is always distributed at regular intervals throughout a polypeptide chain, so there appears to be some recurring pattern. There is also evidence that proteins are made upof units, each containing about 288 amino acid groups, in which the individual types follow such a recurring arrangement.
Proteins are of two general types, fibrous and conjugated. Fibrous proteins are made of up of units of long chain molecules which possess the property of shortening their length parallel to the longitudinal axis. The contractile skeletal muscles are made up of such fibrous proteins. They also enter into the structures of horn, hair, nail, skin and exoskeleton of insects.

Many of the most important proteins, including nucleoproteins, the respiratory pigments and various enzymes are conjugated proteins, having an attached or prosthetic group, which may confer many important properties to the protein molecule. These will be discussed later.

Nucleic acids are nitrogen and phosphorous containing compounds, which can be broken down into a variety of nucleotides including adenylic acid, so, important

in energy transformations. The latter contains a nitrogen base purine, a pentose sugar and phosphoric acid.

Two types of nucleic acid are found, the ribose and 2-desoxyribose forms. The desoxy ribose form is associated with the cell nucleus and heredity. There is considerable evidenced that the nucleoproteins are in general concerned with the synthesis of protein. Both plants and animals contain nucleoproteins, and this is taken as evidence of their common origin.

Enzymes—As is well known enzymes are biological catalysts, which alter the rate of chemical reaction without any rise of temperature, and without altering the direction or the extent of the reaction. Enzymes can be of many kinds: (i) it can be made up wholly of protein molecule (ii) it can have a prosthetic group which may be a simple metallic ion or a nonprotein molecule. In certain enzymes the prosthetic group may be a complicated group like the nucleotide of coenzyme I. Investigations of Tatum and Beadle make it probable that in simple organisms like *Neurospers* and some bacteria, each enzyme is controlled by a gene. I have mentioned before of the macromolecule mitochondria, common to all animals and yeast, is a multienzyme unit containing the full complement of about 100 enzymes necessary for the carrying out of the citric acid cycle and allied processes, discovered by Krebs. In non mitochondrial system e.g., in higher plants all the activities of mitochondria have been duplicated . In such systems the activated substrate is transferred from one enzyme to another and undergo reactions without at any time coming into contact with non-activated molecules. Such a reaction sequence calls for an intimate collaboration of a group of enzymes. The catalytic unit for the over all reaction is no longer the individual enzyme but a team of enzymes.

The last compounds I shall consider in this section are coloured compounds, containing a tetrapyrrole structure, which are active as light absorber as in chlorophyll- or in the transfer of oxygen in the body fluid as heme, the prosthetic group in hemo, globin. In chlorophyll a Mg. atom is at the center of the tetrapyrrole ring,while in heme, Mg. is replaced by iron. The same structure is met with in a number of enzymes connected with the transport of oxygenic respiration in the cytochrome system. In organisms belonging to different genera and species either thestructure of the pyrrole compound or its ratio to the globin is altered (2).

Adaptation and Natural Selection—The discovery that the chemical compounds found in living organisms were confined to a limited number of types, was preceeded more than a century ago by a similar morphological discovery based upon comparative anatomical studies by Owen and others. It was noticed that groups of animals were organized in one or more architectural plan such as that of the Vertebrata, the Arthopoda, the Mollusea and so on. Owen held that in each of the main phyla, there is an underlying plan or archetype built up of a number of similar parts, such as the vertebra of vertebrates, the segments of centipides and worms, the ossicles of Echinoderms[16]. These parts are modified in different species in adaptation to their special conditions of existence. Similarities found to exist in the forms and functions of animals could be classified according to Owen under two different concepts. He defined homologous organs as the same organ in different animals under variety of form and function, e.g., in two such vertebrates as a mole and a bat, the prelimbs have entirely different functions, yet the skeletal plan of the limbs is in both cases the same. On the other hand it is frequently found in the animal kingdom, organs which show remarkable similarity of structure and function but whose bodies are otherwise built upon totally different plans. The wing of a bird and the wing of an insect perform analogous functions. The ability to fly has been developed in them on different lines, the appendage pattern in the insect being totally different from that of the vertebrate. Another example is that the eye of a cuttle fish imitate the eye of a vertebrate, in both case we have the same arrangement of lens, iris, retina, and so on. Though there is some differences in the innervation of the retina, the resemblance is striking. One of the most striking examples of such so called parallel evolution is the development of the brain in insects and

vertebrates; the highest developments have been found in bees and ants on the one side, and in mammals on the other. Bergson pointed out that instinct and intelligent behaviours are on two different lines of evolution, each with its advantages and drawbacks. Instinctive behaviour is characteristics of the little brained type of animals, reaching its climax in ants and bees with a rich repertory of instincts and very little of educability, while the big brained type reached its climax in the higher vertebrates. Speaking of such instances Bergson said whether we will or not we must appeal to some inner directing principle in order to account for this convergence of effect.[16]

The harmonious development of the component organs related to the organism as a whole and their adaptation to the performance of specific functions have attracted the attention of natural philosophers since the ancient times. According to Aristotle, an entelechy or final cause guides the development of an organism from birth onwards. To Owen it appeared that in every species, ends were obtained and the interests of the animals promoted in a way which indicated superior design, intelligence and foresight, in which the judgement and reflection of the animal were never concerned, and which we must ascribe to 'the Sovereign of the Universe' To Lamarck adaptation of the organism to its environment was due to the inheritance of aptitudes acquired during an animal's lifetime. All these different hypothesis were swept aside by the publication of Darwin's *Origin of Species* in 1859. The adaptiveness of the organism to its environment was attributed to the weeding out by natural selection of all chance variations which occured in successive generations, but which were not suited for survival. 'With the knowledge that has been amassed from Darwin's time, it is no longer possible to believe that evolution is brought about through the so called inheritance of acquired character—the direct effect of use or disuse of organs or of change in environment or by the conscious or unconscious will of the organism; or through the operation of some mysterious vital force; or by some inherent tendency i.e., all theories lumped together under the heads of orthogenesis and Lamarckism—are invalidated" Regarding the nature of the variations on which natural selection operates, J. Huxley remarks "In all cases they (the variations) are random in relation to evolution. Their efferts are not related to the needs of the organism or to the condition in which it is placed. They occur without reference to their possible consequences or biological uses—the capacity of the living organism for reproduction is the expansive driving force of evolution; mutation provides its raw material; but the natural selection provides the direction".[10b] In fact 'Natural selection' is creative in the sense that it can and does operate to produce evolutionary novelty. It will only be creative in certain conditions of evolutionary environment; in others it will operate to discourage novelty and to produce and main tain stability"

The view held by many competent biologist of the difficulty of imagining that 'chance' could create a hand or eye or other adaptive organ, no longer, according to Huxley, carry and weight "In fact the 'argument from improbability' has recoiled on the heads of its users, and the apparently incredible complications of an organ must now be taken as additional evidence for the power of natural selection". "It is due to the capacity of natural selection—to combine over a series of generations, a number of mutational steps, each of which by itself is an improbable or rare event; the seperate improbabilities are not merely added up but multiplied by

each other at each new step. What is involved may be clearly pictured when we recall that the number of generations available for the evolution of the human eye for instance, is of the order of 10^8"(10a).

One critic (Roger Pilkington)[17] has remarked "It is difficult to see how natural selection could possibly have selected independently a number of separate anatomical imperfections and gradually build up into a single evolutionary strain when each aberration by itself was useless and perhaps disadvantageous, until accompanied by all others. This is the difficulty in the case of the eye; to tell us that the sheer improbability of natural selection being the responsible agent, is the very proof of its efficacy is just absurd.... To suggest that natureal selection is the only 'effective agency of evolution' is to make an assertion for which there is no evidence whatsoever. Perhaps the insertion of the word 'discovered to date' at the end of the sentence would give us a more realistic picture of the state of our knowledge of the magnificant and baffing evolutionary process"

Biometrical Genetics—Huxley bases his conclusions on some probability calculations by biometrical geneticists like R. A. Fisher and Muller. It may be doubted whether statistical analysis of genetical data can always provide a reliable check on the basic assumptions on which the analysis is based. The following illustration will elucidate my point. The application of statistics to hereditary data was started by Galton and was based upon his cousin Charles Darwin's observations. Darwin while recognizing the occurrence of 'sports' of unitary genetic changes having major effects, nevertheless laid emphasis on small differences whose accumulation and mutual supplementation the greater differences between species would come about. To him important variations were continuous. Galton in his biometrical genetics endeavoured to give quantitative precision to notions of variations and heredity. By this method some amount of success was obtained in expressing variation and likeness between relatives. On the other hand the method could not cope with the evaluation of the simple arithmetical relations found by Mendel to represent discountinuous variations. Mendel's investigations as Mather remarks "must have held a great appeal to the less mathematically minded biologists who as students of heredity and variation before 1900 had doubtless suffered under a biometrical tyranny". The question remained unsolved for sometime whether it could be possible to reconcile Darwinism, biometry, and continuous variation with Mendel's simple arithmetic, and discontinuous variation. In 1918 R. A. Fisher demonstrated that the 'biometrician's own results must follow from Mendelian inheritance, and that their own methods could be used to partition continuous variation in such a way that Mendel's own phenomenon of dominance could be recognized at work"[13] It is likely that at the present moment some of the less mathematically minded biologists are also suffering from the newer 'biometrical tyranny'.

Homology and Analogy—As a physicist not competent to evaluate the statistical methods employed in current genetical studies, I shall confine myself to citing a few examples of homology and analogy, morphological, functional, and biochemical and discuss how far they are explicable interms of Neo Darwinism. Morphological homology has been studied in relation to comparative anatomy which made striking advances during sixty years following the publication of the *Origin of Species*. It was interested particularly with the search for archetypes in the guise of hypothetical

ancestors.[16] One of the problems thrown up was regarding the significance of orthogenesis, a term used to describe the persistence of evolution along certain pathways. Increase in size of horns in successive species of titanothera or the progressive increase in size of canine teeth of sabre tooth tigers are examples frequently cited[2]. These are taken as examples of persistence of a non adaptive series not explicable in terms of natural selection.

Examples of homology occur amongst each species of chemical compound found in living organisms. Homology in comparable enzymes form an interesting study. The enzymatic breakdown of hexose molecules follow a common pathway in many of higher plants animals and microorganisms. The cyclophorase enzyme system which control the Krebs citric acid cycle is common to many animals, microorganisms, and higher plants. In the former two, these enzymes groups are found in the mitochondria, while in higher plants the occurence of such macromolecules has not been reported. It has been shown in many instances, that comparable enzymes found in different species have not identical structures. Thus leaf phosphates of many plants although generally similar in nature, do differ in their characteristic electrophoretic mobilities. Amylases as well as proteases, differ amongst themsleves as to pH optima, inactivation characteristics and other qualities, indicating also a measure of species specificity. This is probably due to the specificity of the conjugate protein groups of these similar enzymes. The hemoglobin of Vertebrates consist of a protoheme a tetrapyrrole structure, attached to a globulin molecule whose specificity varies with the species.

The limited variability of the molecular species which are found throughout the whole kingdom of living organisms, also imply a limited degree of variability of the gene molecules which controls the de velopment of the organisms. This is not surprising, since the gene molecules are nucleoproteins. The chance mutation of genes is thus possible within a very restricted range, and that may account for the occurence of orthogenesis.

Another enzyme system responsible for transport of oxygen in respiratory systems, the cytochromes is present both in plants and animals. These compounds are evidently of more primitive origin than the heme series of pigments, which are associated with circulation of fluids in higher organisms. The continuation of the same basic pattern of the tetrapyrrole structure in chlorophyll, in the heme series of pigments, and in the cytochromes, while evolutionary changes of great magnitude have been taking place should give the appearance of direction in evolution. It might be described as orthogenic trends. The morphological orthogenetic trend may in some way be related to the biochemical one viz., to the limited freedom of large molecules to modify their structure (2. p. 188).

Analogy—There are again instances where the same function is being performed in different groups of unrelated organisms by analogous structures. Erythrocruorin (invertebrate hemoglobin) appear in widely separated species, between which there is no evidence of genetic relation ship. There is a haphazard distribution of these respiratory pigments, many of which have modified tetrapyrrole structure or which may contain iron but no heme, or which has neighter iron nor tetrapyrrole ring, as in hemocyanin. Here there is no evidence of orthogenic trend, but rather there is evidence of a few patterns have been used quite unsystematically for analogous functions. Again while the tetrapyrrole chlorophyll is

most widely distributed in plants as light absorber in photosynthesis, there are other chromoproteins which can act in this capacity, like phycocyanin and phycoerythrin, in which the prosthetic groups are open tetraphyrrole compounds. (2)

Another group of instances relate to the appearance of the same substance or function or organ in quite unrelated organisms. A hemoprotein which performs identical function of oxygen transport has been found in the root nodules of leguminous plants. Astbury and Weibull[1] have studied the X-ray diagrams of bacterial flagella in *Proteus* and *B. subtilis*, which show patterns very similar to that of fibrous protein of skeletal vertebral muscle. On the other hand the x-ray pattern of algal flagella has not so far revealed any discernable similarity. I shall refer to the very interesting review by Dr. Pantin[16] for similar examples of repeated appearance of complicated structures in unrelated zoological groups, and content myself by giving some examples of appearance of analogous structures in plants.

Analogous functions in plants—Growing regions of plants show tropistic responces to light, gravity, and mechanical stimulations. The plants possess receptor organs developed for the perception of specific stimuli. The photoreceptor in plants contain some carotenoid compound; in animals the photoreceptor organs from the lowest to the highest are conjugate proteins to which carotenoid containing prosthetic groups like rhodopsin, phorphyropsin are attached. The goeperceptor organs in animals consists of fluid filled chamber, the bottom or top of which contains a sensory epithelium. A solid or semi solid body the statolith, rest or hangs from this epithelium. Any change in the alignment of the organism displaces the statolith and releases self aligning reflex activities. The geoperceptive layers in the growing regions of plants, stems and roots, contain layer of starch granules which according to Haberlandt are the geoperceptive statoliths in plants. By their displacements in a horizontally placed young plant, the stem is caused to point upwards, and the root tip downwards. Similarly there is a great deal of similarity in the behaviour of sensitive hair like structures found in certain plant organs, like the tendrils and on certain parts of the skin of animals. These perform the part of mechanoreceptors. The tropic curvature produced in plants is related to the direction of an electric field produced in the receptor layer, such that the concave side is always electronegative. In analogous receptor organs of animals, the effect of stimulation of the receptor is to produce a change in electric potential at the junction of the receptor to the attached affector nerve.

The leaf system of some of unrelated species of plants e.g., *Desmodium gyrans* (*Leguminosae*) and *Oxalis acetorsella* (*Oxalidaceae*) perform rythmic pulsations during the day; the best example is found in the small lateral leaflets of *Desmodium gyrans.* Each mechanical pulsation is accompanied by an electric one. It has been found that the source of energy for mechanical pulsation is the oxidation of sugar formed in the leaflet by photosynthesis. The mechanical pulsations are accompanied by pulsations in the respiration of the leaflet.[4a,6]

The hair like algae *Nitella, Chara* show all the characteristics of isolated nerves. Mechanical, chemical stimulation of one end, can give rise to single or repititive propagated excitations of an electrical nature. In the sensitive plant *Mimosa pudica* (*Leguminosae*) the stimulation of one part of the stem is conducted as an electric excitation, which elicits mechanical closure of the pulvinus and attached leaf system. Such excitations are

subject to the same kind of amplification or depression by means of cold block, flow of electric current or chemical agents, as are found effective in an animal nerve muscle unit. The mechanical response to stimulation may be either single or repititive. Further a chemical substance which can be isolated by hotwater extraction of macerated Mimosa stems, when introduced within the cut end of a revived stem pulvinus unit of mimosa, can produce single or repititive discharges of the pulvinus leaf system—its role is analogous to that of acetyl choline[4a]. *Biophytum sensitivum* (*Oxalidaceae*) also exhibit similar characteristics of mechanical response to transmitted stimulation.

Examples from Embryology—Other instances of appearance of similar functional processes in unrelated animal organism, is to be met with in the methods adopted for embryonic development.

> "Egglayying has been abandoned and living birth has been independently resorted to by many groups of invertebrates (Molluscs, Insects, Arachnida and Crustaceans) and Vertebrates (Fish, Amphibia, Reptiles and Mammals).
>
> How these needs are satisfied is familiar to students of Embrylogy. Well known too that these highly complex structures of the embryonics states have been developed many times in complete independence.
>
> If after a consideration of all these marvellous temporary organs and structures we turn to post natal life, we are almost forced to admit that what is developed before birth is almost more perfect in its adaptation than anything that is developed after the embryonic period is passed. That the embryonic developments are directly developed towards the satisfaction of the specialized needs of the embryo seems impossible to deny—at least we might say that it is difficult to extend Charles Darwin—Alfred Wallace theory of evolution, by means of chance variation acted only by natural selection, to what happens before the individual rubs shoulder with the world"[24].

Some Theoretical Conclusions

Before proceeding further it will be useful to review some of the theoretical conclusions which can be drawn from the materials I have placed before you, on the nature of the living organism.

(1) The organism can be considered as an autonomous unit through which there is a continuous flow of matter and energy. On the one side there is increase of entropy due to break up of the energy rich compounds accompanied by respiration and elimination of waste products, which on the other hand is compensated by the organism absorbing negative entropy from some system coupled with the organism, one of which is the donor and the other the acceptor; these changes take place according to thermodynamic laws. Does it imply that the living organism is a machine? It is possible to construct automaton which can perform cycles of operations, in which energy is taken in from either a heat or water reservoir, and the whole or part of it is discharged into a sink and at the same time perform work. To keep such machines going, certain amount of human supervision is required, to mitigate the effect of frictional waste of materials and to prevent breakdown. Such machines cannot replicate themselves, they also require human ingenuity and direction for their planning and construction. Does this indicate that an additional directive principle, other than the known laws of physics and chemistry, becomes active? Philosophers have coined the word 'emergence' for any new property emerging in an assembly of material units, which is not a sum of the properties of the individual components. We have to assume that potentialities for life and mind, are inherent in material units and it requires certain state of accretion for their emergence. The principal characteristic

of a living organism is its capacity for self maintenance in a changing environment. Additional property is that of self replication, with which is associated a limited degree of variation. The last character provides the basis for evolution.

(2) How does this increase in organisation conform with the postulates of the law of entropy, which requires that in an isolated system, like the universe, there is an irreversible tendency to pass from a lower to a greater randomness in the distribution of matter and energy. As mentioned earlier, according to Weizsacker, the second law of thermodynamics allows us to conclude from the existence of forms, that some thing still more improbable had existed in the past, an energy namely capable of producing form. The local increase in organization is associated with increased randomness of distribution of matter and radiation elsewhere. Cosmological examples are the creation of galaxies, stars, the solar system with its planets. Here the gravitational potential became effective in producing forms and the energy released during the condensation of matter is converted into thermal radiation. Similarly on the earth, lowering of temperature made possible the appearance of molecular species, crystals, and rocks, for which a corresponding amount of chemical affinity potential was set free and transformed into heat radiation. Finally with increase in complexity of chemical molecules, a new state of accretion of matter became possible, viz. the thermolabile self replicating protein molecules which became the fabric of the living organism. In the beginning the earth was rich in potentialities and poor in actual forms, rich in creative possibilities poor in created structures. With the coming of life one of the creative potentiality became an actuality, there by diminishing the total available potentiality of the earth.

Organic Design—The living organisms are built up of a limited number of molecular species, the carbohydrates, the proteins, the nucleoproteins, the enzymes and so on. These molecules are again built up of a limited number of atoms; their structure and mode of interaction are based upon laws of physics and chemistry. Their continued production for millions of years in organisms which passed through different stages on the evolutionary scale, from protozoa to man, show that their existence is not dependent on natural selection. The organism has a number of functional requirements connected with metabolism. It has to be provided with mechanism for reception of stimuli from the environment, by means of receptor organs, a central nervous agency for the reception of messages, and for the sending out of orders to motor organs. By such means the purposive self preservative activities of the organism are carried out. For such multifarious activities, a limited number of constructional units are available, out of which the organism can be built up. It is also noticed that for the satisfaction of the same functional requirement, alternative plans of construction are available.

Dr. Pantin[16] has drawn an interesting analogy between the assembly of a living organism out of the limited number of available biochemical building blocks, to that of a model made out of a child's engineering constructional set, consisting of standard parts with unique properties, of strips plates and wheels. These can be utilised for various functional objectives, such as cranes and locomotives. Generalising, on this, he says 'in this universe of ours any functional problem must be met by one or other of a few possible kinds of solution. If we want a bridge, it must be a suspension bridge or cantelever bridge, and so on. And the engineer who

constructs the bridge, must choose whichever of the solutions he can best employ with the standard parts at his disposal. In the design of a bridge there are in fact three elements; the classes possible in this universe, the unique properties of the materials available for its construction; and the engineer takes the third place by selecting the class of solution, and by utilizing the properties of the materials to achieve the job in hand. He is in a sense executing one of a set of blue prints already in abstract existence; though it requires insight to see that the blue print is there".

I mentioned earlier, that in the conditions prevalent at the period of the formation of the universe, when the elements were created, were implicit all the possible future forms and events which could take shape during the subsequent history. These are the blue prints of Dr. Pantin or entelechies of Aristotle. Which of these did or did not materialize at any time in any particular region of the universe, depended upon the conditions prevailing there, and they may be considered as contingent or accidental. We become aware of the blue prints only when we see them actually realized. Assumptions of the existence of such blue prints raises embarassing metaphysical problems, such as were discussed by Plato in his doctrine of forms or ideas.

Applying these ideas to the construction of living organisms, it follows according to Pantin, that like all material structures they must conform to certain constructional principles. Blue prints of many of them, Pantin finds, in D'Arcy Thompson's book '*Growth and Form*,' The standard parts available for the construction are the biochemical building blocks. Like the engineer, natural selection takes the third place by giving reality to one or other of the series of possible structural solutions with the materials available. There are two sets of designs involved. One of them refer to the design of the component parts, of the biochemical units; these we have seen are not the results of natural selection in the Darwinian sense. The over all design on the other hand, is selected by natural selection. This equating of natural selection with the engineer by Pantin, is open to criticism. All engineering designs, before they come in general use have to pass the test of fitness. Innumberable aeroplane models were tried and failed, before successful flight was achieved by the Wright brothers.

Putting into existence in living organism alternate solutions of certain structural problems is to be attributed in my view, to the mechanism which controls the production of novelties in living organisms i.e., when gene mutation takes place. According to this view, mutations are not all entirely random events in the sense defined by Julian Huxley, but are partly of a directed or teleological nature, due to, it is to be presumed, some activity of the psyche, which even in the subconscious level we must associate with the living organism, from the initial stage of its evolution. Probably it is to this psychic element is to be attributed the autonomous activities which characterize the living organism. Accoreing to Lillie, the essential peculiarity of vital organization—as contrasted to the non-living part of nature—is that spontaneous factors, whose activities are internally determined and largely independent of present envioronmental condition and past history, are somehow enabled to assert themselves in a unified and effective manner. Physical research has shown that single microphysical events have a certain degree of indeterminacy in the sense of not being completely predictable; thus no one can predict to which of the possible atomic orbits in an excited atom, an electron will jump back.

Predictability enters only when a large number of such events are considered; it is a statistical predictability[11].

Of this nature are the decisions taken by human beings at critical situations, the average statistical behaviour of such a person may be predictable, like accidents, death rates, the number of suicides, and so on, each of which has its individual as well its external determination. However this indeterminate characteristic which exhibits itself in simple physical events, becomes in some manner an essential factor in the control of the whole complex system. Of this nature is the control exercised by individual gene on the development of the organism. Gene mutations are believed to be transitions between metastable states of the constituent nucleoprotein molecules. Generally such transitions are of a random character. It is part of my thesis, that under extreme situations such transitions may be directively controlled by the unconscious psyche of the organism. They do not violate any macrophysical laws, but only alter the statistical weight amongst the different permissible transitions. The extreme situation referred to above arise, when the organism has to cope with special environmental situations, and mutations are directed to provide one or other of the functional solutions compatible with the available biological materials. It is on such mutated organisms that natural selection acts.

I am very much aware that there are many unsurmountable difficulties, which I have no time to discuss here, in picturing how directed mutations acting over several generations can produce a structure adapted to the altered environment. I will end this section with a quotation from Lillie (11, p. 107) in which an analogous situation has been discussed, how spontaneous activities can arise in organisms.

> "According to the present view, some element of indeterminacy—in the sense of present determination, or internal determination, or what may be called "spontaneity" is always present in a natural event, but to a degree which varies greatly in the different instances. Within the vital organization this internal determination is apparently able to express itself in a way which is not possible in non-living systems; the latter are more directly dependent for their determination on factors external to themselves. Such a conclusion has the advantage of not dividing living systems sharply from non-living systems, and is consistent both with physics and with the rytheo of organic evolution. I may add that I do not underrate the difficulty of understanding how a present activity can have a property which is independent of past conditions. But equally I do not 'understand' the natural characteristic of creativity, which, nevertheless is an undeniable fact, as human experience and evolution both show. This characteristic is ultimate, as Whitehead insists; and on the basis of immediate experience, as well as of our scientific knowledge, it seems justifiable to refer it to psychical rather than to purely physical factors, since psychical events are, in a sense peculiar to themselves, a manifestation of novelty or spontaneity as well as of the individuation which is a main characteristic of nature".

Communication and Control—I now return to the topic with which I started, the discovery that physiological principles of communication and control observed in living organisms has been employed by human beings for similar purposes in the machines constructed by them. J. C. Bose was a pioneer in this line of thought. I find it very suggestive that recent developments in communication technique, based upon electromagnetic theory, electronics, and ultrasonics, which were introduced during the last two wars, should have led to the discovery that analogous methods of communication were already being employed by animal organisms; a study of the electronic circuits employed in the construction of computing machines should have given us for the first time a satisfactory working

model of the brain. It is difficult for a physicist to accept the view that the principles of communication based upon applications of electromagnetism and electronics, the result of several generations of intelligent human effort, could have been evolved in living organisms by chance variations acted upon by natural selection. Consideration of such problems has led me to believe in the possibility of psychic factor being responsible for giving directional gene mutations.

Animals, unlike plants, have to seek for their food, which may be other animals. For this purpose they have developed mechanism for locomotion, and perception of external objects. The animal receives a message through one of its receptor organs, eye, ear etc., which is conveyed as excitation along an afferent nerve to a nerve centre, from where an order is sent out along effector nerves to muscles controlling the appropriate muscular organs. The most widely developed receptor organ in animals is the photo receptor. The object to be located must be either self luminous or made visible by diffuse reflection of sunlight or artificial light. The normal eye fails in its function in the absence of light, during the night, in dark caves, in muddy waters, or in the depths of the sea. Some animals have developed alternative modes of perception for location of objects.

The sense organs in the facial pit of blind folded crotalids—rattle snakes, copper heads, and moccasins—mediate the ability to strike correctly at moving objects such as dead rats, cloth covered light tbulbs, end to distinguish between warm and cold objects. Radiant energy appears to be the effector stimulus. The electric activity of the receptor organ has been studied and it is found to be specially sensitive to radiant heat in the region 1 to 10-15μ with maximum between 2-3μ. As with many other receptor organs, the connecting afferent nerve is traversed by a barrage of rythmic pulses, whose form is modified when infra red radiation is incident on the receptor[7]. Some fishes employ detector of pressure waves and ripples in water, to locate other swimming fishes. The lateral lines of a cat fish is traversed by barrage of rythmic pulses which is modified by impact of pressure waves received from the surrounding. Such detector mechanism enable the fishes to keep oriented when they move in schools (16, p 506).

In the above instances the organism is a passive receptor of message sent out from some other sources. There are groups of animals who use the principle of echo ranging, first employed during the first war to detect the position of submerged enemy submarines. For this purpose pulses of ultrasonic radiations were sent out at regular intervals. In between the pulses, the beam reflected from an object is received by a pair of detectors from which the position of the reflecting object could be located. This echosounding technique has been used subsequently to measure the heights of the reflecting layers in the ionosphere. For this purpose pulses of e.m. waves of different wave lengths are employed

In the more recent technique of communication, frequency modulated pulses are used in which the frequency instead of being kept constant is varied between certain limits. The echo sounding technique employing very short e.m. waves has been used to locate enemy airplanes. Originally anti aircraft guns were directed towards the enemy planes by manual operation, after the radar had located it. Later the reflected beam was used as message to automatically direct the fire of the guns. Here the principle of feed back is employed about which I shall speak later.

Insect devouring small bats *Myotis*, *Pipistrellus* are known to be able to fly in complete darkness. Blind or blindfolded bats can fly normally and capture their preys and they are known to be able to avoid obstacles formed by a net work of wires, with great skill. It was found that on closing the ears these animsls lost their faculty of avoiding obstacles. Later it was proved that the animals emit through their open mouth pulses of ultrasonic radiations of continuously varying frequency from 30-120 kilocycle per second; the pulse duration varies between 1 and 3 m.sec., and the number of impulses emitted per second varied from 20-30 for normally flying bats to 50 to 150 per sec., when the animal is flying fast or approaching an obstacle. The pulses sent out are what is known as frequency modulated, and has a maximum intensity at 50 kc/sec. During flight these bats turn their heads in all directions, like a search light, and thus employ the echo ranging technique to locate hard obstacles. All the details of the method of location are not well understood, specially when the animal is so very near an obstacle, that is receives the reflected echo at the same time it is emitting sound pulses. One of the explanation offered is, that the animal adjudges distance by perception of the difference tone between the emitted and reflecteed beam, a kind of heterodyne reception.

Mohres[14] describes another family of echo ranging bats, widely separated from the *Mikrochiropidae* (var. *Verspertilionidae*) named *Rhinolophidae.* Round the nose of this animal, there is a cone like attachment made of skin, whose opening can be varied by muscular adjustment. In this type of bats the ultrasonic waves are emitted through the pair of nasal holes with the mouth shut. The sound pulses are undamped and monochromatic, of frequency which varies between 80-100 kc/s according to the different types of animals, and are emitted for 90-100 m/sec. The variable cone like opening as well the interference between the sound waves emiitted through the pair of nasal openings, separated by half a wave length distance, help to focus the monochromatic sound beam along the median direction perpendicular to the nasal opening. The head is rotated through a cone of 120° opening, and obstacle location is evidently not based on the echoranging principle.

*Some recent observations of W. N. Kellong and Robert Kohler made on captive porpoises kept in the Oceanographic Institute, Florida, show that these animals can hear sound of frequencies upto 50 kcs. The authors infer that porpoises like bats not only hear but also emit ultrasonic radiations and use an echo location technique to locate objects, including preys during night or when submerged in muddy waters. (Science, 5-9-52 p. 250).

Electric organ and Radar mechanism—I have in a previous section (ante p. 10) described how in electric fishes the electric organs consisting of columns of electroplaxes, each containing upto 400, have developed from degeneration of muscles. In the electric eel with lengths upto seven feet, the guts are crowded into the first fifth of its length, leaving the remaining four fifths filled almost entirely by a jelly like electroplaxes. When stimulated by nerve impulses from the brains, all the plaxes are discharged in series simultaneously. To compensate for the time lag which the nerve impulses from the brain may take to reach the top and bottom layers of the electroplaxes, the short nerve lengths are provided with delay devices, probably in the spinal chord, which compensates almost exactly the differences in nervous conduction times. In the electric eel, only the tail muscle have been converted into electric organ. In the *Torpedo*, one of the muscles which normally move the gills, has been adapted for this purpose. Another

electric fish, popularly known as the Stargazer, has its electric organ developed from the eye muscle, while in the electric cat fish of the Nile, the electric organ did not start from a muscle at all, but developed from glands on the skin[11]. A better example of analogous evolution of the same functional organ in unrelated species of fishes, in response to a particular environmental situation could hardly be found. That some of these electric fishes could send out continuous beam of electric pulses was described by H. N. Lissmann[13]. The hind end of the fish *Gymnarchus niloticus*, and particularly the finger like tail are known to contain tissues corresponding to an electric organ. Probably the electric organs in other fishes like the electric eel (*Gymnotus*), the *Torpedo* or the electric ray may have developed from similar electric pulse emitting organs as in *Gymnarchus*. The pulse freququency vary between 215 to 318 pulses per second, at temperatures between 21°–31.5°C, probably they are of the nature of relaxation oscillations. The fish can detect the pulses emitted by it and reflected from metallic obstacles, as well as pulses emitted by other sources of similar range of frequency. The fishes could steer extraordinarily well when going backwards, evidently without seeing where it was going. Lissmann has found that other fishes like *Mormyrops boulengers* and *Gymnotus carapo*, agree will in all essential features with *Gymnarchus niloticus* though there is a marked difference in pulse shapes and frequencies.

Feedback principle—The mechanism by which these animals locate objects, is one of the innumerable applications of the principle of feed back control of the activities of animals and of machines, either for the purpose of maintaining the *status quo* or for guiding the performance of such organisms towards some defined objectives. Any deviation of the present activity of the organism either from a *status quo* or from approach towards a defined objective, is fed back as information by a receptor mechanism to the controlling agency, calling forth appropriate reactions which opposes such deviation—hence the name negative feed back. I cite some examples.

A thermostatic relay is employed to keep the temperature of a bath constant within certain prescribed limits; this is done by controlling the supply of heat to the bath, such that with rising temperature the heat supply is reduced and vice versa. The rotating governors in a steam engine control the supply of steam from the boiler to the moving parts, by cutting off steam when the machine is going too fast. The speed of the engine is thus kept constant under varying loads. In a radio circuit variations in the output due to fluctuations in the imput signals, is stabilized by automatic volume controls. Regulators based upon feed back principle are being increasingly used in many industrial processes.

Complex biological organisms can maintain a nearly constant internal enviornment in face of an external environment which change all the time, often suddenly and unpredictably. Human beings would die quickly if it were not for such characteristics as the intricate thermostat that keeps the body within one or two degrees of its normal temperature. Blood pressure, acid-alkaline ratios, sugar levels in muscle and liver—these and many other factors are regulated within definite limits to maintain health. Distributed all over the body, both on the surface and inside, are receptor organs which are continuously sending messages to the controlling centers in the brain, and when any deviation from the normal state occurs appropriate remedial reactions are set in operation.

Other set of feed backs refer to our postural and voluntary efforts. As I am sitting on a chair and writing, my sitting posture is maintained

by a series of reflexes, based upon messages from what are called stretch receptors attached to muscles controlling posture. Voluntary action is often based upon messages received from outside. A thirsty person sees a glass of water placed on a table. It releases in him a set of muscular activities whose aim is to lift the glass of water from the table and place it to the lips. The eyes continually gauges the distance between the hand and the table. The information is telegraphed to the brain, which passes orders to the arm, hand, and wrist muscles. The first part of the process is completed when the hand has touched the glass. Raising the glass to the lips calls forth a similar cycle of muscular activities, based on information supplied by the eye. The controlling factor in such cases is the degree in which the act is not completed. Some time it happens that effector mechanism which the negative feed back activates, has a lagging characteristic; a compensating arrangement is then provided which is of the nature of an anticipator or pedictor. When a sports-man goes out duckshooting, the error be tries to minimize is not the position of the gun and the actual position of the target, but with the anticipated position of the latter. Every system of antiaircraft fire control, has a predictor mechanism to compensate for similar lag effect in the aiming of the guns.

Mechanical Brain—Computer machines based upon electron relay circuits are employed for fast computation and they perform their operations in an analogous way to the human brain. All the data (information)are inserted at the beginning of the operation. The electron tubes employed have a remarkable similarity to the human brain nerve cells. The machine remembers, chooses between alternatives, checks their own results, and perform so many human operations that in describing them, free use is made of human terms like memory, judgment. The fundamental characterisation shared by brain and computers are, that they are both devices for receiving informations and use them to achieve results and solve problems.

Compared to the brain with its 10 billion nerve cells, the calculating machine is bulky, using in the Eniac about 18000 tubes which dissipate several kilowatts of power. Such machines can do arithmetic faster and more accurately than people, they can make elementary judgments, learn in a fashion, remember thousands of numbers and instructions, and forget by simple opening of a switch. They solve the problems men invent, but cannot frame new theories or tell people how to build apparatus to check them.

Body and Mind—The living organism has in the higher evolutionary stage evolved an integrating nervous mechanism which it uses to maintain its internal environment at some desired level, as well as to react purposively to some changes in the external environment. These activities have been imitated in a large measure in servomachines, in radars, and in electronic computers. Thus both the metabolic activities as well as those responsible for control and communication in the organism can be described in terms of laws of physics and chemistry. On this plane of activity, the organism is an energy system whose activities take place in space and time.

Side by side with the growth in complexity in the nervous organisation which integrates the motor activity of the organism, mind, recognizable mind, appears to have arisen. What was this mind at the beginning, germinating in the primitive animals as appurtenance to motricity? Natural selection had brought it; it had some survival value. From it as

common germ, has sprung several types of mental experiences, affect (feeling), conation (will), cognition (intellect). What is the relation between the physical and the mental aspects of human behaviour? In the same cerebral process, on the one side electrical brain potentials with thermal and chemical action, compose the physiological entity held together by energy relations, on the other side, suite of mental experiences, activity no doubt but what if any in relation to energy? There are suggestions for redefining energy so as to bring mind into it. But this according to Sherrington is not possible (20). The puzzle appears to be not unlike that in the interpretation of the dual aspect of the behaviour of photon, as well as of matter generally, viz., the necessity of describing them both as particles as well as waves. To overcome this difficulty Bohr formulated his principle of complementarity viz., the complete description of a 'photon' or of a material particle, is not possible either from the wave aspect or from the particle aspect; but they complement each other. Similarly the description of the activity of a human being, of which only we have a first hand experience, will not be complete if considered only as an energy system whose activities can be described in space and time, or simply in terms of insensible, i.e., not directly perceptible to the senses, unextended mind. The mind aspect as well as the energy aspect of the organism can interact with one another, so that its motor behaviour can be due either to an extrinsic cause i.e., dependent on messages received through the sense organ or to an intrinsic one i.e., the activity is initiated by some mental state of the organism.

Mind as a factor in Evolution—What has been the role of mental processes in biological evolution? According to Huxley "Gene mechanism can not by its nature directly transmit experience or knowledge acquired by the individual organism or the effect of the environment on the organism. It can indeed transmit no mental experience, but only the capacity for having a certain kind of experience, including in certain animals the capacity for learning by experience. It is a purely material mechanism and cannot be operated or transformed except by the difficult and often wasteful material process of selection, natural or artificial"[10a]. With the gradual evolution of the higher vertebrates, mind instead of being a mere 'appurtenance to motricity' began to exert a directive influence on the behaviour of organisms. We speak of intelligent behaviour,. when there is evidence of the organism understanding a new situation, and has as well the capacity to vary known methods to apprehend a new desirable objective. In higher vertebrates also, there is some sort of training or education of the offsprings by the parents. But it only bridges the gap between one generation and the next, so that its effect is not cumulative, and there is nothing we can call an organ of experience, common to the entire species. The mental functions of life were brought in to being by natural selection and transmitted indirectly by the vehicles of gene complex. "Before the human level, mental functions and activities have not succeeded in invading the evolutionary process itself".

In man, development of the techniques of communication by means of speech and writing has made possible a new method of transmission of experience, not only between individuals of the same generation, but between succeeding generations. Thus according to J. Huxley[10a] was brought into being a new genetics—the genetics of the human society—resting upon a mental or psychological basis of socially transmissible ideas, emotions, or attitudes. One field of human activity where deliberate

attention has been given to the technical problem of how to acquire, transmit and accumulate experience—the field of natural science—the advancement has been most extraordinary. In the sphere of social genetics, the creative factor, the agency for production of novelty, has been solely the contribution by the mental faculties of man.

The recognizable mind we know of is a product of evolution, and appears at a certain stage when the organism had achieved nervous integration. To explain this appearance, we have to assume with Huxley, that the world stuff possesses not only material properties, but also rudimentery potentialities of mental properties. The question then arises, whether we have to restrict the activity of the mind stuff in the creation of novelty in social genetics only, after the organism has attained a certain technique of communication. To many biologists it appears unreasonable to rule out the possibility, of the psyche exercising some influence in the sphere of biological genetics viz., by influencing gene mutation, the biological mechanism for introducing novelty in organisms (ante p. 19). This stand point has been advocated specially by Lillie, with which I myself with my limited knowledge of biology, am inclined to concur.

How does J. C. Bose's conclusions quoted in the beginning fit in with the picture of the relation between (ante p. 1) the non-living and the living I have sketched, and which is based upon investigations extending over the last fifty years. So long as the living organism is considered only as an energy system, his conclusions, though based on very limited data, still remain astonishingly valid. It was an intuition or inspired guess, and was possible in the pantheistic tradition of his country. On the other hand the mental activities of the higher organisms, affect, conation, and cognition, escape his conclusions.

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SECTION OF MATHEMATICS

PRESIDENT: V. V. NARLIKAR

Presidential Address

FROM GENERAL RELATIVITY TO A UNIFIED FIELD THEORY

1. INTRODUCTION

After a succession of brilliant attempts following his affine field theory of 1923 Einstein arrived, in 1950, at a generalization of the relativisitic theory of gravitation which appeared to him "highly convincing'. It was developed on the lines of his paper published in 1945 the results of which were subsequently modified by his work in collaboration with E. G. Straus (1946). An exposition of the theory as it stood then was given by Einstein in 1948. The implications of this theory were examined by Narlikar and Ramji Tiwari (1949 *a*, *b* and *c*) who showed that there was no interaction between the gravitational field and the electromagnetic field up to the second order of approximations and who also carried on the calculations up to the third order to establish the Maxwell equations as modified by the gravitational field of the sun. This was followed by a fresh revision of the field equations (Einstein 1950).

As yet the theory has solved no physical problem and the question naturally arises whether a generalized field theory of this kind can ever enter effectively into theoretical physics. Einstein's approach clashes with Bohr's principle of complementarity and runs counter to the conception of physical reality according to the philosophy of quantum mechanics. It is not possible to envisage at this juncture what mathematical methods will be ultimately useful in bringing under the sway of one theory the far-flung domains of gravitational, electromagnetic and quantum phenomena. There are potentialities in the mathematical methods of the field theory which we may not ignore and an attempt is therefore made here to pass under review some of the mathematical problems of the field theory of macroscopic physics, although its measure of success is far from satisfactory.

2. HAT IS A FIELD ?

The Newtonian law of gravitation is characterized by action at a distance. The action is moreover instantaneous and how it occurs is a mystery. Newton had no hypotheses to frame regarding the instantaneous propagation of action at a distance. One can use the principle of sufficient reason and argue as Birkhoff (1950) has done to deduce the inverse square

law of attraction. In the case of an isolated mass particle the force per unit mass is derivable from a potential function

$$A/r+B, \tag{2.1}$$

where A and B are constants and r is measured from the position of the mass particle. Now this function is the only solution of spherical symmetry of the simplest rotation-invariant differential equation

$$\nabla^2\phi=0\,. \tag{2.2}$$

Herein Einstein got the first clue that "this function was to be considered as determined by a law of space". Any such explantion was aesthetically satisfying inasmuch as it revealed why Nature preferred the inverse square law to any other. It paved the way for the field theory. "The transition from particle physics to field physics is undoubtedly one of the greatest, and as Einstein believes, the greatest step accomplished in the history of human thought" (Infeld 1941). In the earlier, mechanistic theory of Newton things happen only at particles. In the field theory things happen everywhere else except at particles. "To use Hilbert's term the description of the world according to the field theory consists of the here-thus relations—the here being represented by the space-time coordinates, the thus by the state quantities. If the latter are given as functions of the former the world is completely known" (Weyl 1949*i*). Maxwell's electromagnetic theory is the first such model of the field theory—a model with its own imperfections.

It is interesting to find from the history of mathematics that one and the same idea, viz., Leibniz's continuity principle was responsible for the development of field physics on one hand and that of differential geometry on the other. "Only in the infinitely small may we expect to encounter the elementary and uniform laws, hence the world must be comprehended through its behaviour in the infinitely small" (Weyl 1949*ii*). Thus the field physics of general relativity and Riemannian geometry may be looked upon as mathematical twins. It is well-known that both Riemann and Clifford anticipated in their speculations the twentieth century geometrization of gravitational physics.

An n-dimensional affine space E_n is given by the coordinates x^k subject to the transformations of the affine group

$$x'^k=a^k+A_l^k x^l \tag{2.3}$$

where $$\text{Det } (A_l^k)\neq 0 \qquad k, l=1,2,\ldots n\,. \tag{2.4}$$

All such coordinate systems are the allowable coordinate systems of E_n the coefficients A_l^k and a^k being constant. We can similarly define an n-dimensional manifold X_n of points each of which is given by the coordinates ξ^k or ξ'^k the only restrictions on the transformation in the region of validity being that ξ^k are analytic functions of ξ'^k with

$$\text{Det } (A_l^k)\equiv\text{Det } \left(\frac{\partial\xi'^k}{\partial\xi^l}\right) \tag{2.5}$$

being non-zero at each point in the region. Thus the coordinate systems of X_n are connected by the more general group of invertible analytic transformations while the coordinate systems of E constitute the affine group of

linear transformtions in n variables. At each point $P\ (\xi^k)$ of $^{\text{''}}{}_{\imath}$ it is possible to have a local E_n the transformations of allowable coordi. .te systems being characterized by the constants

$$A_l^k = \left(\frac{\partial \xi'^k}{\partial \xi^l}\right)_P. \tag{2.6}$$

A geometrical object ϕ is said to be defined at the point P in X_n provided it has the same number N of components in each of the allowable coordinate systems x^k, x'^k etc. of the local E_n and provided further that if ϕ_A are the components in the x^k-system and ϕ'_A in the x'^k-system each of the ϕ'_A is linear and homogeneous in the components ϕ_A, is algebrically homogeneous in $\left(\frac{\partial \xi'^k}{\partial \xi^l}\right)_P$ and does not involve the higher derivatives of ξ'^k with respect to ξ^l at P. If the geometrical object ϕ is thus defined at each point in a region of X_n we have a ϕ-field in the same region.

For a scalar field $N=1$, for a vector field $N=n$ and for a general tensor field with r suffixes $N=n^r$.

The gravitational potential of the Newtonian theory is a scalar field defined in a region of a three dimensional flat space. The vector potential of the Maxwell theory provides an illustration of a vector field in flat space space-time. In general relativity we have a tensor field defined in X_4.

Let us consider a geometrical object, say, a contravariant vector given by

$$B^k = B^k(\xi^l). \tag{2.7}$$

at a point $P(\xi^l)$ in X_n. In the local E_n at P we can represent it by

$$B'^i = B^k \left(\frac{\partial \xi'^i}{\partial \xi^k}\right)_P. \tag{2.8}$$

The same geometrical object is represented at a neighbouring point $Q(\xi^l + d\xi^l)$ in X_n by

$$C^k = C^k(\xi^l + d\xi^l). \tag{2.9}$$

In the local E_n at Q we have

$$C'^i = C^k \left(\frac{\partial \xi'^i}{\partial \xi^k}\right). \tag{2.10}$$

Since the constants of transformation of the allowable coordinates at P and Q are different the functional forms at P and Q of the same gemetrical object differ. If X_n were E_n we would have found

$$C^k = B^k + dB^k. \tag{2.11}$$

The differenc between X_n and E_n is brought out by the assumption that we make of

$$C^k - B^k - dB^k. \tag{2.12}$$

One may as well assume that for an arbitrary contravariant vector field

$$C^k = B^k + dB^k + B^j \Gamma_{jl}^{\ k}\, d\xi^l + \lambda^k_{\ i}\, d\xi^i - B^k (B^j \mu_{jl}\, d\xi^l + v_i\, d\xi^i) \tag{2.13}$$

where $\Gamma_{jl}^{\ k}$, $\lambda_i^{\ k}$, μ_{jl} and v_i define the structure of X_n. A still more general relation can be introducted as has been done by König (1920). In the physical field theories that have been seriously considered so far the simpler relation is adopted, viz.,

$$C^k = B^k + dB^k + B^j \Gamma_{jl}^{\ k}\, d\xi^l \tag{2.14}$$

involving only the affinity $\Gamma_{jl}^{\ k}$. We have here in the affinity a new type of geometrical object differing from the ϕ-object considered above inas much as the laws of transformation in the local E_n involve also the derivatives of $\dfrac{\partial \xi'^k}{\partial \xi^l}$ at P.

As suggested by the above analysis we have the covariant derivative of B^k :

$$B^k{}_{;l} = \frac{\partial B^k}{\partial \xi^l} + B^j \Gamma_{jl}^{\ k}. \tag{2.15}$$

We can similarly have the covariant derivatives of other geometrical objects such as a scalar ψ, a covariant vector D_k and a tensor $T^{ij\cdots\cdots}_{kl\cdots\cdots}$. Thus

$$\psi;l = \frac{\partial \psi}{\partial \xi^l}\,. \tag{2.16}$$

$$D_k; l = \frac{\partial D_k}{\partial \xi^l} - D_i \Gamma^i_{\ kl}. \tag{2.17}$$

$$\begin{aligned} T^{ij\cdots\cdots}_{kl\cdots\cdots};p = {} & \frac{\partial}{\partial \xi^p} T^{ij\cdots\cdots}_{kl\cdots\cdots} \\ & + T^{\alpha j\cdots\cdots}_{kl\cdots\cdots}\Gamma^i_{\alpha p} + T^{i\alpha\cdots\cdots}_{k\ l\cdots\cdots}\Gamma^j_{\alpha p} \\ & - T^{ij\cdots\cdots}_{\alpha l\cdots\cdots}\Gamma^\alpha_{kp} - T^{ij\cdots\cdots}_{k\alpha\cdots\cdots}\Gamma^\alpha_{lp} + \cdots \end{aligned} \tag{2.18}$$

By covariant differentiations of ϕ—type geometrical objects we generate other ϕ—type objects and the field equations of physics are partial differential equations which usually signify that some geometrical object in a region in X_n vanishes.

Although the field laws describe how the local happenings in a local E_n at P are mutually correlated the influence of the whole of X_n with its special geometrical structure is not altogether absent. It enters surreptitiously through the choice of the partial differential equations of the field. The latter are deduced by a variational principle applied to the integral of a world function taken all over X_n. "The true significance of variational

principles in special cases remains extremely obscure. For example, an arbitrary set of ordinary differential equations is readily given variational form in a limited part of the domain of the variables. It is only the fact that there is a single explicit variational form available in the entire domain of the independent variables that is really significant. Possibily this interesting situation indicates that the basic importance of the variational principles will be found to be topological" (Birkhoff 1943).

At the close of the last century the success of the field concept in physics was an established fact mainly through the researches of Faraday. Kelvin and Maxwell. Hamilton's principle which could be used so successfully in machanics was an instrument of research even in the electromagnetic theory. There was no satisfactory explanation of action at a distance. The stage was set for making attempts first to establish gravitation as a purely field theory and next to unify gravitational and electromagnetic theories in one generalized field theory. The task of fulfilling this programme in natural philosophy was taken up by Einstein. But even before he had begun it Planck's quantum of action was on the scene in 1900.

3. General Relativity as a Field Theory

It is said that in special relativity we are always at c—the velocity of light -whereas in general relativity we are always at sea. The Newtonian dynamics still works as a first approximation to the facts of nature although Newton admitted in all humility that he was just toying with a smooth pebble or a pretty shell while the great ocean of truth lay all undiscovered before him. Let us therefore marshall the salient facts leading to Einstein's problem.

The Newtonian theory postulates a unique inertial frame although there is no dynamical criterion to distinguish it from any other space moving uniformly with respect to it in some fixed direction. For the group of transformations which sums up the resulting ambiguity both space intervals and time intervals are invariant. The most important feature of the theory is the law of gravitation, unequalled in its range of success and yet philosophically so unsatisfactory on account of the instantaneous propagation of gravitational action at a distance. The discovery of a finite velocity of light in 1675 by Römer followed by the discovery of light as an electromagnetic phenomenon and of the atom as governed by electromagnetic laws led to the conjecture that the physical universe is of electromagnetic origin. The Newtonian theory obviously required a correction for the infinite velocity of propagation of the gravitational force.

In the special theory of relativity there is an infinity of inertial frames mutually connected by Lorentz transformations. The velocity of light is c in each frame as required by the Michelson—Morley experiment and the "separation" ΔS of two events $P\ (x, y, z, t)$ and $Q(x+\Delta x,\ y+\Delta y,\ z+\Delta z,\ t+\Delta t)$ as given by

$$(\Delta S)^2 = c^2(\Delta t)^2 - (\Delta x)^2 - (\Delta y)^2 - (\Delta z)^2, \tag{3.1}$$

in the usual notation, is invariant. Lorentz referred to ΔS as local time. The theory explains how the inertia of a particle increases with speed and establishes the equivalance of energy E and mass M through

$$E = Mc^2. \tag{3.2}$$

It gives a unified treatment of electric and magnetic fields showing how either field may be zero in one inertial coordinate system and non-zero in another. The Maxwell equations which had appeared so artificial in structure in their original form could be recast as simple tensor equations when their invariance with respect to the Lorentz group became known.

According to general relativity a flat space-time with its infinity of inertial frames implies absence of gravitation. When the events of a situation can be described as the points of an X_4 governed by a Riemannian metric

$$ds^2 = g_{\mu\nu} dx^\mu dx^\nu \tag{3.3}$$

$$g_{\mu\nu} = g_{\nu\mu} \tag{3.4}$$

of rank four and signature two we have a gravitational field. It is not possible by any non-singuler Gaussian transformation to reduce the metric with its ten potential functions $g_{\mu\nu}$ to the form

$$ds^2 = c^2 dt^2 - dx^2 - dy^2 - dz^2. \tag{3.5}$$

Thus a gravitational situation can be described only in the setting of a curved space-time. According to Galileo's experiment when bodies of different masses are dropped from the same high spot they reach the earth at the same time. This is a case of uniform gravitational field which can be transformed away. Møller (1952) calls such gravitational fields non-permanent and distinguishes them from the permanent ones with a curved space-time. But even in a permanent gravitational field it is possible to use real quasi-coordinates and express in the local E_4 at any point P the metric as

$$ds^2 = c^2 dT^2 - dX^2 - dY^2 - dZ^2. \tag{3.6}$$

The principle of general relativity requires that all fundamental laws of nature be expressible by equations covariant under the general group of non-singular Gaussian transformations. This group includes the group of Lorentz transformations. The tensor equations fulfil the requirements of the principle of general relativity.

By the principle of equivalance the motion of test particles and of light rays is given by identical laws whether the space-time is flat or curved. Light rays trace null geodesics and the test particles non-null geodesics. It is well-known that the metric potentials $g_{\mu\nu}$ become completely known through the projective and conformal properties of the metric space. The motions of test particles provide the necessary knowledge of the projective properties and the propagation of light yields the rest of the information. The equivalance principle is also supposed to mean that even in a permanent gravitational field the field at any point P in X_4 can be transformed away within a neighbourhood of first order displacements. This is obvious from the construction of the local E_4 and the theory of geodesic coordinates. All laws of nature can be expressed at P by means of the quasi coordinates of the local E_4 in the same from as in special relativity.

A necessary and sufficient condition for a space-time region to be flat is that at every point

$$R_{hijk} = 0, \tag{3.7}$$

where the left-hand side represents the Riemann-Christoffel curvature tensor. A region of permanent gravitation is one in which

$$R_{hijk} \neq 0. \tag{3.8}$$

Further, if it is unoccupied by matter

$$R^h{}_{ijh} \equiv R_{ij} = 0. \tag{3.9}$$

If

$$R_{ij} \neq 0 \tag{3.10}$$

there is said to be a distribution of matter in the region as given by the energy momentum tensor T_{ij} in natural units:

$$R_{ij} - \tfrac{1}{2} R g_{ij} = -8\pi T_{ij}, \tag{3.11}$$

where

$$\mathrm{R} = R_{ij}\, g^{ij}. \tag{3.12}$$

In view of the fourfold arbitrariness of the coordinate systems only six out of the ten $g_{\mu\nu}$ may be considered free and six equations independent of the coordinate systems are needed to determine them. They are provided by the field equations (3.9) and (3.11). Although the field equations appear to be ten in number they are effectively six only on account of the identities

$$(R^{ij} - \tfrac{1}{2} R\, g^{ij})_{;\, j} = 0 \tag{3.13}$$

and the conservation laws

$$T^{ij}{}_{;\, j} = 0. \tag{3.14}$$

The field equations (3.9) and (3.11) are the analogues of

$$\nabla^2 V = 0 \tag{2.15}$$

and

$$\nabla^2 V = -4\pi\rho, \tag{3.16}$$

Laplace's and Poisson's equations respectively of the Newtonian theory. Once we commit ourselves to having a Riemannian metric for the X_4 of space- time and it is accepted that the field equations will be partial differential equations of the second order for $g_{\mu\nu}$ a survey of the possible world functions forces us through

$$\delta \int R\sqrt{-g}\, dx^1\, dx^2\, dx^3\, dx^4 = 0, \tag{3.17}$$

where

$$g = \mathrm{Det}\ (g_{\mu\nu}), \tag{3.18}$$

to the field equations (3.9) and the identities (3.13). Einstein was never satisfied with the hybrid character of the equation (3.11) of which he compared the right-hand side to a pillar of straw as distinguished from the left-hand side, purely a field entity, which he thought was a pillar of marble. It was a provisional formulation to be replaced by a pure field equation of some total field, accounting for forces other than gravitational.

The equation (3.9) with which Einstein was quite satisfied as a field equation makes the metric dependent upon the gravitational situation,

This is considered as a serious defect in the logical structure of relativity by Whitehead, Milne, Birkhoff, Rosen and others. The following quotation from Barajas and others (1944) reveals the main ground of their criticism:

"With regard to the first, it should be recalled that the connection between matter and geometry,as developed by Einstein is purchased at the expense of giving up a fundamental reference system. This implies abandoning the description of nature in terms of four fundamental independent varie ables, essentially unique except for the arbitrariness involved in position and velocity of a single point (Lorentz group). In the abandonment of such coordinates may be discerned a sufficient reason for the early exhaustion of all observational tests of the general theory of relativity, and also for the fundamental difficulty of assigning physial meaning to the coordinates introduced in the problems of this theory. Indeed, almost thirty years of intensive research have failed to provide another test besides the three crucial ones, or to apply the theory to other fields of physics........ Even in the simple case of Schwarzschild's solution of the one-body problem, no clear-cut physical interpretation of the Schwarzschild coordinates seems to be available."

The problem in which Einstein was immdiately interested was finding a solution of the field equations (3.9) free from singularities all over X_4. The first nontrivial solution which brought success and prestige to the theory was Schwarzschild's metric, viz.,

$$ds^2 = -\left(1-\frac{2m}{r}\right)^{-1} dr^2 - r^2\,(d\theta^2 + \sin^2\theta\, d\phi^2) + \left(1-\frac{2m}{r}\right) dt^2 \qquad (3.19)$$

where m is interpreted as the positive mass constant of a body at the origin of space coordinates. It was with the help of this metric that the close quantitative agreement between the theory and experiment was demonstrated so far as the three crucial tests were concerned. A light ray from a distant star grazing the limb of the sun suffers a deflexion of 1.75″. After an examination of the experimental data Dyson and Woolley (1937) say: "The conclusion is that the displacement is at least as great as 1.75″ and possibly a little greater but not more than 2.0″." The theoretical estimate of the advance of the perihelion of Mercury is 42.9″ per centary which accounts beautifully for the observed discrepancy. Astronomers agree that the redshift in the spectrum of the sun and of the companion of Sirius is in satisfactory agreement with Einstein's prediction. The opinion is still expressed in certain quarters that all these verifications are inaccurate (Louis de Broglie 1949).

These successes led Larmor (1927) to examine the status of general relativity in relation to the Newtonian theory and he described the former as an auxiliary construct—auxiliary to the latter. General relativity can be used unhesitatingly and unambiguously for comparing empirical data with the theoretical courterpart when the latter is independent of coordinate systems. Apart from its fourfold arbitrariness the metric of general relativity and hence the coordinate system also remain unknown until the field equations are fully solved. No agreement between theory and experiment can be satisfactory until it is certain that the same coordinate system is used in both kinds of work. Objecting to the heterogeneity of space-time and its dependence on matter and motion in general relativity Whitehead (1922) writes: "The structure (of the continuum of events) is uniform because

of the necessity for knowledge that there be a system of uniform relatedness, in terms of which the contingent relations of natural factors can be expressed. Otherwise we can know nothing until we know everything." One has therefore to view with some scepticism the successes regarding the three crucial tests.

In (3.19) there is a singularity at $r=2m$. This can be explained away as of no consequence if the formula is taken as valid for $r>>2m$. The field equations (3.9) break down as r diminishes, even before the value $2m$ is attained. In 1941 Einstein was able to demonstrate the non-existence of gravitational fields with a non-vanishing total mass free of singularities. A couple of years later Einstein and Pauli (1943) were able to prove the non-existence of regular stationary solutions of relativistic field equations. For a generalized theory of gravitation Papapatrou (1948) has obtained a similar result.

Can any physical significance be attached to other solutions of (3.9) with one or more singularities? Narlikar and Karmarkar discovered in 1946 the solution:

$$ds^2=-dx^2(1+kt)^p-dy^2(1+kt)^q-dz^2(1+kt)^r=dt^2 \qquad (2.20)$$

where k is an arbitrary constant and p, q, r are constants subject to the conditions

$$p+q+r=2, \qquad pq+qr+rp=0. \qquad (3.21)$$

For this line-element not only $T^{\mu\nu}=0$ but the pseudo-tensor density of gravitational energy and momentum also is zero everywhere in X_n:

$$t_\mu{}^\nu=0. \qquad (3.22)$$

It follows that if p, q, r are real they must lie between 2 and $-2/3$. One particular case of interest is

$$p=-\tfrac{2}{3}, \qquad q=r=\tfrac{4}{3}. \qquad (3.23)$$

There is a singularity when

$$1+kt=0. \qquad (3.24)$$

A solution with two apparent singularities which was discovered by Silberstein in 1936 created quite a stir. It seemed that a reason had to be given for rejecting the solution according to which there was to be no gravitation between two mass particles or the field equations of general relativity had to be given up as false. Einstein and Rosen (1935) write as follows:

"The question with which we are concerned can be put as follows: Is an atomistic theory of matter and electricity conceivable which, while excluding singularities in the field, makes use of no other field variables than those of the gravitational field ($g_{\mu\nu}$) and those of the electromagnetic field in the sense of Maxwell (vector potentials, ϕ_μ)?"

The authors then refer to the singularity in Schwarzschild's and Reisner's solutions and to the difficuty caused by the divergence of the contravariant electrical field density, apparently excluding the existence of electrical particles. Later they observe:

"For these reasons writers have occasionally noted the possibility that material particles might be considered as singularities of the field. This

point of view, however, we cannot accept at all. For a singularity brings so much arbitrariness into the theory that it actually nullifies its laws. A pretty confirmation of this was imparted in a letter to one of the authors by L. Silberstein."

A closer scrutiny of Silterstein's solution by Einstein and Rosen (1936) revealed that there were concealed in it other singularities in addition to the two singularities which were supposed to represent two mass particles. It was possible that if the latter two were endowed with suitable motion the additional singularities surreptitiously present in the solution might disappear. If the field equations were correct and if no non-trivial solutions free from singularities existed it was only proper to enquire if the field equations did not give the equations of motion as well, through solutions of moving singularities. Since matter and motion cannot be divorced from each other it is not satisfactory that matter be given by the field equations and motion by the geodesic postulate. The gravitational equations (3.9) are unlike Maxwell's equations non-linear in character. This fact and the existance of the four identities (3.13) were used by Einstein, Infeld and Hoffmann (1938) to deduce the equations of motion of particles as moving singularities from the field equations (3.9) themselves. It was no longer necessary to assume the mass of the moving body in a problem of n bodies to be negligible. General relativity can now give us the equations of motion of one component of a double star about the other. It was verified by Narlikar (1941) that the equations of motion thus obtained are consistent with the geodesic postulate. A new and improved version of the theory of motion was given recently by Einstein and Infeld (1949).

One may note in passing the effect on the solution of the dynamical problem in general relativity on account of the indeterminateness of the coordinate frame. Suppose that the equations are solved and the coordinates of a particle are known as functions of time:

$$\xi^1 = f(\xi^4), \quad \xi^2 = \phi(\xi^4), \quad \xi^3 = \psi(\xi^4). \tag{3.25}$$

The solution will be of little use for astronomical purposes on account of the heterogeneity and indeterminateness of the coordinate system. A meaning can be given to the dynamical solution only in a coordinate system in which an isolated body moves with a uniform velocity. Papapetrou (1951*b*) has examined the coordinate conditions in relation to the equation of motion. He finds it necessary to dissolve the connection between the metric and gravitation and in his theory $g_{\mu\nu}$ are mere gravitational potentials as in Rosen's (1940) theory of gravitation in flat space-time. In the pure field theory of motion of Einstein and Infeld $T_{\mu\nu}$ has no place and hence Papapetrou (1951*a*) argues that gravitational forces which are more significant than the relativistic forces in the equations of motion and which arise through the oblateness and other asymmetric features of gravitating bodies are unaccounted for in their theories. Papapetrou has himself obtained such equations. But in doing so he has gone back to Newton's inertial frame and he leans on the pillar of straw $T_{\mu\nu}$. In this, matter ceases to be space-time curvature.

4. The Need of a Unified Field Theory

A perfect field theory gives a representation of moving mass particles free of singularities. As general relativity cannot do away with mass point singularities Einstein has conjectured that when the theory is complete with electromagnetic features one should find a total field, everywhere regular, and

providing a more satisfactory representation of matter and motion. The phenomenon of the gravitational deflexion of light suggests that there may be other phenomena arising out of an interaction of the electromagnetic and gravitational fields. There are speculations that there may be a connection between the angular momentum of a body and its magnetic moment. Clark's (1950) calculations of the external gravitational and electromagnetic fields support the Wilson—Blackett (1947) hypothesis. Such interactions can be the subject proper of study in a unified field theory of gravitation and electromagnetic phenomena. Faraday was of the persuasion that all forces of nature are manifestations of something more fundamental which would feature in a unitary theory. The existence of variational principles playing a fundamental role in different branches of mathematical physics lends strength to the belief that such a unitary theory is possible. For many years the chiefest problem for Einstein has been the construction of a total field theory which would be a natural generalization of general relativity.

The theoretical investigations on these lines steer clear of quantum mechanics and run counter to the principle of complementarity. While Einstein has been concerned with physical reality in the macroscopic domain the formulation of the physical problem in the microsopic domain has taken a new turn. For the measurement of two non-compatible physical variables in quantum mechanics, which appear as non-commutative algebraic elements in the theory, mutually exclusive experimental arrangements become necessary. The essence of the principle of complementarity lies in this that the experimental knowledge of partial systems thus acquired cannot, when pooled together, be used to form a unified complete picture of the whole physical system. According to Einstein this only shows that the quantum mechanical formulation of the physical problem is wrong. He believes that the programmatic aim of all physics is "the complete description of any (individual) real situation (as it supposedly exists irrespective of any act of observation or substantiation)."

On the other hand Louis de Broglie (1949) remarks: "Moreover, the nature of the electromagnetic field is so intimately bound to the existence of quantum phenomena that any non-quantum unified theory is necessarily incomplete. These are problems of redoubtable complexity whose solution is still "in the lap of the gods". He points out that the geometrical method has succeeded in the case of gravitation because of the equivalence of kinematic and gravitational masses. The method breaks down for electrodynamics because "electromagnatic forces are proportional to the charge, and not to the mass of the body upon which they act." It is well-known how Aston made use of this property in his mass spectrograph. In the methods that are generally used to unify the two fields this difference between their characters does not receive prominent notice. The mathematical distinction between the two fields is that one is given by a symmetric tensor and another by a skew-symmetric tensor. The problem is a mathematical one of unifying the two tensors irreducibly so that solutions of the field equations which are everywhere regular describe gravitational and electromagentic phenomena in conformity with observation.

A unified field theory on the lines on which Weyl, Eddington, Einstein, Schrödinger and others have tried to develop it, is considered to be deterministic as against the probability-ridden modern quantum mechanics according to which the Powers in charge of the material universe are said to be playing dice. The alternative to playing dice as Max Born (1949) has pointed out is solving innumerable differential equations.

There is a superficiality about the attempts at unification made so far. As Weyl (1949*iii*) has observed "The rigid rods and the clocks by which Einstein measures the fundamental quantity ds^2 of his metric theory of the gravitational field preserve their length and period in the last instance because charge c and mass m of the composing elementary particles are preserved." In the total field to be constructed objects more fundamental than $g_{\mu\nu}$ must appear.

5. Mathematical Features of a Non-Linear Field Theory

We will use in this section the notation of P.G. Bergmann (1949). In an X_4 with a permissible coordinate system x^ρ let there be a set of N variables y_A ($A=1,2,\ldots N$) and let partial derivative of y_A with respect to x^ρ be shown as $y_{A,\rho}$. The first difficulty in the construction of a unified field theory is about the selection of the Lagrangian function L. If the Lagrangian equations are to be of the second order L must be a function of y_A and $y_{B,\rho}$ only. If there are any terms involving second order derivatives of y_A in L their contribution in

$$\delta \int L dx^1\, dx^2\, dx^3\, dx^4, \tag{5.1}$$

where the integral is taken all over X_4, should be zero on account of Green's theorem and the condition that $\delta y_A=0$ at the boundary. This is precisely what happens in (3.17). The field equations then take the form

$$\partial^A L-(\partial^{A\rho} L)_{,\rho}\equiv L^A=0. \tag{5.2}$$

In the above and in what follows the comma is used to indicate partial differention with respect to the variable or variables indicted by the following suffix or suffixes. For the change of coordinates

$$x'^i=f^i(x^\rho) \tag{5.3}$$

we assume the law of transformation for y_A:

$$y'_A \equiv \sum_B F^{B\rho}_{A\sigma} \; y_B \; \frac{\partial f^\sigma}{\partial x^\rho} \tag{5.4}$$

For the infinitesimal transformation

$$x'^i=x^i+\delta x^i \tag{5.5}$$

we have

$$\delta y_A=\Sigma F^{B\rho}_{A\sigma}\; y_B\; (\delta x^\sigma),\; \rho. \tag{5.6}$$

The value of δy_A at x^i is

$$\bar{\delta} y_A=-y_{A,i}\, \delta x^i+\Sigma F^{B\rho}_{A\sigma}\; y_B\; (\delta x^\sigma),\; \rho. \tag{5.7}$$

The coefficients $F^{B\nu}_{A\mu}$ are a set of constants characteristic of y_A. They have to satisfy certain relations if the infinitesimal trasformation law (5.7) is to

generate the law of a finite transformation. For this the condition is that if $\bar{\delta}_1$ and $\bar{\delta}_2$ are two infinitesimal operators of the above type $\bar{\delta}_3$ as given by 4

$$\bar{\delta}_1\,\delta_2-\bar{\delta}_2\delta_1=\bar{\delta}_3 \qquad (5.8)$$

should also be of the same type. This gives

$$F_{A\mu}^{\ \nu}\ F\ {}_{\rho}^{\sigma}-F_{A\rho}^{C\sigma}\ F\ {}_{\mu}^{\nu}=\delta_{\rho}^{\nu}\ F_{A\mu}^{B\sigma}\ -\ \delta_{\mu}^{\sigma}\ F_{A\mu}^{\ \nu}. \qquad (5.9)$$

It is necessary that the Lagrangian be such that

$$\bar{\delta}L=Q^{\rho}{}_{,\rho} \qquad (5.10)$$

as a result of which

$$\bar{\delta}L^{B}=-F_{A\mu}^{B\nu}\,(\delta\ x^{\mu})_{,\nu}\ L^{A}-(L^{B}\delta x^{\mu}),\ \mu. \qquad (5.11)$$

We find that

$$Q^{\rho}\equiv F\ {}_{A\mu}^{B\rho}\ y_{\mathrm{B}}\ L^{A}\ \delta\ x^{\mu}+\partial^{A\rho}L\ \bar{\delta}y_{A}. \qquad (5.12)$$

Since

$$\int L^{A}\bar{\delta}y_{A}=0 \qquad (5.13)$$

we have from (5.7) and (5.13), by integration of parts, the four identities

$$F_{A\mu}^{B\rho}\ (L^{A}y_{B})_{,\rho}+L^{A}y_{A,\mu}=0. \qquad (5.14)$$

Considering the coefficients of the thi l order derivatives of y_A on the left in (5.14) we get the identities:

$$\left(F_{A\mu}^{B\rho}\ L^{AC\sigma\tau}\ +F_{A\mu}^{B\sigma}L^{AC\ \rho}+\ F_{A\mu}^{B\tau}\ L^{AC\rho\sigma}\right)\ y_{B}=0, \qquad (5.15)$$

where

$$L^{AC\rho\sigma}\ =\ -\tfrac{1}{2}\ (\partial^{A\rho}\ \partial^{C\sigma}\ L+\partial^{A\sigma}\ \partial^{C\rho}\ L). \qquad (5.16)$$

By the very definition of $L_{,i}$ we have

$$\begin{aligned} L,{}_{i}&=y_{A,i}\,\partial^{A}L\ +\ y_{A},\ k_{i}\ \partial^{Ak}L\\ &=Y_{A,i}\,(\partial^{Ak}L),\ k\ +\ Y_{A,\ ki}\,\partial^{Ak}L\\ &=(Y_{A,i}\,\partial^{Ak}L)_{,k} \end{aligned} \qquad (5.17)$$

on using (5.2). Thus

$$t^{\rho}_{i,\rho}\ =0 \qquad (5.18)$$

where

$$t^{k}{}_{i}=\delta_{i}^{k}L-y_{A,i}\,\partial^{Ak}L. \qquad (5.19)$$

Here we have expressions for the energy-momentum fluxes and densities.

The equations of motion can be obtained in an ingenious way by the method of parametrization as shown by Bergmann and Brunnings (1949). Four new coordinate functions u^1, u^2, u^3 and t are used as independent variables and y_A and x^ρ are treated as their functions. The four identities (5.14) and the four equations (5.18) which are the Lagrangian equations corresponding to x^ρ are used as in general relativity to obtain the equations of motion by successive approximations.

We have sketched above the essential mathematical steps in the construction of a unified field theory. There are other known patterns of unified field theories such as that of Horvath's (1950) theory but we do not follow them here.

The possibilities that have been recently considered by Schrödinger (1947, 1948*a*, 1948*b*) for constructing a non-linear unified field theory are the following:

(1) sixteen $g_{\mu\nu}$ components as y_A ; $N=16$

(2) sixty-four $\Gamma^\lambda_{\mu\nu}$ components as y_A; $N=64$

(3) $g_{\mu\nu}$ and $\Gamma^\lambda_{\mu\nu}$ as y_A; $N=80$

At the outset one has to select a suitable Lagrangian. The second case arises in the purely affine theory and here, following the early work of Eddington (1921), Schrödinger takes

$$L=\frac{2}{\lambda}\sqrt{-\text{Det } R_{\mu\nu}} \tag{5.20}$$

where $R_{\mu\nu}$ is the Einstein tensor:

$$R_{\mu\nu}=-\frac{\partial\Gamma^\sigma_{\mu\nu}}{\partial x^\sigma}+\frac{\partial\Gamma^\sigma_{\mu\sigma}}{\partial x^\nu}+\Gamma^\rho_{\mu\tau}\,\Gamma^\tau_{\rho\nu}-\Gamma^\sigma_{\rho\sigma}\,\Gamma^\rho_{\mu\nu}. \tag{5.21}$$

λ which appears in (5.20) is a constant.

$$\int L d\tau=\int\frac{\partial L}{\partial R_{kl}}\,\delta R_{kl}d\tau, \tag{5.22}$$

where $d\tau$ stants for the four—dinensional volume element. The tensor density $\mathfrak{g}^{kl}$ is defined by

$$\lambda\mathfrak{g}^{kl}=-\frac{\text{cofactor of } R_{kl}}{\sqrt{-\text{Det } R_{\mu\nu}}}. \tag{5.23}$$

If $$g=\text{Det }\mathfrak{g}^{kl}, \tag{5.24}$$

$$g^{kl}\sqrt{-g}=\mathfrak{g}^{kl} \tag{5.25}$$

and $$g\lambda^4=\text{Det } R_{\mu\nu} \tag{5.26}$$

we have $$R_{kl}=\lambda g_{kl} \tag{5.27}$$

where $$g_{k\sigma}g^{l\sigma}=g_{\sigma k}g^{\sigma l}=\delta^l_k. \tag{5.28}$$

The field equations themselves are obtained from the vanishing of

$$\delta \int L d\tau = \int (G_i^{kl} - \delta_i^l \; G_\sigma^{k\sigma})\delta\Gamma_{kl}^i \, d\tau = 0 \tag{5.29}$$

where

$$G_i^{kl} = \mathfrak{g}_i^k + \mathfrak{g}^{\sigma l}{}^*\Gamma_{\sigma i}^k + \mathfrak{g}^{k\sigma}\,{}^*\Gamma_{i\sigma}^l \tag{5.30}$$

$$-\tfrac{1}{2}\mathfrak{g}^{kl}({}^*\Gamma^\sigma{}_{i\sigma} + {}^*\Gamma^\sigma{}_{\sigma i}$$

$${}^*\Gamma^i{}_{kl} = \Gamma^i{}_{kl} + \tfrac{2}{3}\delta^i{}_k\Gamma_l \tag{5.31(}$$

$$\Gamma_l = \tfrac{1}{2}(\Gamma^\sigma{}_{l\sigma} - \Gamma^\sigma{}_{\sigma l}).$$

From the laws of transfornation it is obvious that Γ_l is a vector. For the star affinity it can be verified that

$${}^*\Gamma^\sigma{}_{l\sigma} = {}^*\Gamma^\sigma{}_{\sigma l}\,. \tag{5.33}$$

The field equations are

$$G_i^{kl} - \delta_i^l G^{k\sigma}{}_\sigma = 0. \tag{5.34}$$

If $l=i=\sigma$ we have $G^{k\sigma}{}_\sigma = 0$ (5.35)

and hence $G_i^{kl} = 0$ (5.26)

or $g_{ik,l} - g_{\sigma k}\;{}^*\Gamma^\sigma{}_{il} - g_{i\sigma}\;{}^*\Gamma^\sigma{}_{lk} = 0.$ (5.37)

This may also be expressed as

$$R_{ik,l} - R_{\sigma k}\;{}^*\Gamma^\sigma{}_{il} - R_{i\sigma}\;{}^*\Gamma^\sigma{}_{lk} = 0. \tag{5.38}$$

As Schrödinger interprets these equations "the Einstein tensor R_{ik} is transformed into itself on a certain parallel displacement by the star affinity."

If $g^{ik} = g^{\underline{ik}} + g^{\overset{ik}{\vee}}$ (5.39)

so that $g^{\underline{ik}} = g^{\underline{ik}},$ (5.40)

$$g^{\overset{ik}{\vee}} = -g^{\overset{ki}{\vee}}, \tag{5.41}$$

we can derive from (5.35) the equation

$$g^{ik}, k = 0. \tag{5.42}$$

The four identities and the expressions for the energy-momentum fluxes and densities follow in this case precisely as in the general case treated above.

In a theory like this one has to seek a suitable symmetric tensor of two covariant suffixes for the expression of the gravitational field and a suitable skew-symmetric tensor of two covariant suffixes for the expression of the

electromagnetic fields. For the gravitational metric we may have either g_{kl} or s_{kl} as given by

$$s = \text{Det } \mathfrak{g}^{kl} = \text{Det } s_{kl} \tag{5.43}$$

$$s^{kl} = \frac{\mathfrak{g}^{kl}}{\sqrt{-s}} \tag{5.44}$$

$$s^{kl} s_{km} = \delta^l_m. \tag{5.45}$$

For the electromagnetic field we have several skew fields such as

$$g^{\underset{\vee}{ik}}, \quad R_{\underset{\vee}{ik}}, \quad g_{\underset{\vee}{ik}} \tag{5.46}$$

etc. There is no superfluity here of mathematical possibilities because the physical problem of a truly unified field has to account for more than the gravitational and Maxwell fields.

The mixed field theory for which the non-symmetric Γ^i_{kl} and g_{kl} play the role of y_A and for which the field equations follow from the Lagrangian

$$L = R_{kl}\, \mathfrak{g}^{kl} \tag{5.47}$$

is equivalent to the unified field theory of Einstein and Straus (1946). In the latest modification of the theory Einstein adopts

$$\Gamma_l = 0 \tag{5.48}$$

and, therefore, as (5.31) shows, the distinction between the starred and the unstarred affinities disappears.

Students of gravitational theories have a number of critical observations to make about the methods of general relativity and about its postulates and hypotheses. The laws of general relativity owe their power to the invariance with respect to the Gaussian group of transformations. The policy, however, of not committing oneself to a particular frame, which gives so much power becomes a source of ambiguity and embarrasment in the solution of the n-body problem (Petrova 1949). The propagation of light is marked by $ds=0$ but it invariably takes place in the direction of increasing t. A theoretical justification of this has yet to be found out (Weyl. 1949*iv*). If a light signal starts from A and reaches B is it right to say always "B after A", when A and B as world-points in X_4 are arbitrarily separated from each other? Gödel (1949) has drawn our attention to this. General relativity does not recognise anything like the two time-scales of Milne's theory nor does it provide an explanation of the sign and magnitude of the gravitational constant γ (Milne 1944). It is contended by Milne that the field equations of gravitation presuppose a certain structure for the world substratum and that it is not therefore correct to use the equations for obtaining the substratum structure as is done in relativistic cosmology. The method of differential geometry fails to bring out the distrinction between incongruent counterparts such as the right hand and the left hand in terms of the relativist's X_4 (Northrop 1941). W. Sherrer (1949) and several Japanese workers have examined the logical difficulty of making the space-time frame contingent upon matter and motion. There is the difficulty in classical physics of

formulating the equations of motion when there are excessive collision velocities (Birkhoff 1937). The same difficulty arises in general relativity when the velocity of disturbance in a fluid is exceeded by the relative velocity of collision. Hosts of other questions exist such as that of the equations of fit raised by Narlikar and others (1942*a* and *b*). Max Born (1949)who finds the physical significance of the line-element "rather mystical" in an X_4 suggests that the infinitesimal element ds may be replaced by a finite length Although they are all fundamental questions Einstein has set them aside and taken in hand the problem of unification of fields because he believes that only a unitary theory can effectively replace the general relativity solutions involving singularities by solutions of field quations which are everywhere regular.

The equations of the generalized theory must be invariant with respect to a group in no way narrower than the group of Gaussian transformations. If the group is too wide the equations are too general and further criteria are necessary to exclude the solutions which are wide of the physical mark. Einstein, in his latest theory, does not widen the group but he chooses a non-symmetrical g_{ij}-field. Using the notation already introduced for symmetric and skew-symmetric quantities we have

$$g_{\mu\nu}=g_{\underline{\mu\nu}}+g_{\underset{\vee}{\mu\nu}}. \tag{6.1}$$

The contravariant tensor $g^{\mu\nu}$ is defined by

$$g_{\mu\nu}\, g^{\mu\sigma}=g_{\nu\mu}\, g^{\sigma\mu}=\delta^{\sigma}{}_{\nu}. \tag{6.2}$$

Similarly the affinity symbols also are non-symmetric:

$$\Gamma^{\lambda}{}_{\mu\nu}=\Gamma^{\lambda}{}_{\underline{\mu\nu}}+\Gamma^{\lambda}{}_{\underset{\vee}{\mu\nu}}, \tag{6.3}$$

$$\Gamma^{\lambda}{}_{\nu\mu}=\Gamma^{\lambda}{}_{\underline{\mu\nu}}-\Gamma^{\lambda}{}_{\underset{\vee}{\mu\nu}}. \tag{6.4}$$

There are, thereforofe, two kinds of covariant derivatives:

$$A^{i}{}_{+};_{k}=A^{i}{}_{,k}+A^{s}\,\Gamma^{i}{}_{sk} \tag{6.5}$$

$$A^{i}{}_{-};_{k}=A^{i}{}_{,k}+A^{s}\,\Gamma^{i}{}_{ks} \tag{6.6}$$

$$A_{\underset{+}{i}};_{k}=A_{i,k}-A_{s}\,\Gamma^{s}{}_{ik} \tag{6.7}$$

$$A_{\underset{-}{i}};_{k}=A_{i,k}-A_{s}\,\Gamma^{s}{}_{ki}. \tag{6.8}$$

In the above and in what follows the semi-colon behind a suffix is used as usual to denote covariant differentiation. From these definitions one has

$$A^{i}{}_{0};_{k}=A^{i}{}_{,k}+A^{s}\,\Gamma^{i}{}_{\underline{sk}} \tag{6.9}$$

$$A_{\underset{0}{i}};_{k}=A_{i,k}-A_{s}\,\Gamma^{s}{}_{\underline{ik}}. \tag{6.10}$$

Following the variational principle.

$$\delta \int g^{\mu\nu}\,\sqrt{-g}R_{\mu\nu}\,d\tau=0, \tag{6.11}$$

for a mixed theory, where $R_{\mu\nu}$ is defined for the affinity

$$\Delta^{l}_{ik}=\Gamma^{l}_{ik}-\tfrac{1}{3}\left(\Gamma_{i}\delta^{l}_{k}-\Gamma_{k}\delta^{l}_{i}\right), \tag{6.12}$$

the following field equations are obtained:

$$R_{ik}=0 \tag{6.13}$$

$$g^{\overset{i}{+}\overset{k}{-}}{}_{;\,l}=0 \tag{6.14}$$

$$\Gamma_{i}=0. \tag{6.15}$$

In the earlier version of his theory Einstein had used in stead of (6.13) the two equations

$$R_{\underline{ik}}=0 \tag{6.16}$$

$$R_{\underset{\vee}{kl},m}+R_{\underset{\vee}{lm},k}+R_{\underset{\vee}{mk},\,l}=0 \tag{6.17}$$

of which the former is contained in (6.13). (6.17) is a condition weaker than

$$R_{\underset{\vee}{kl}}=0. \tag{6.18}$$

The electric current density is found to be given by the tensor

$$g_{\underset{\vee}{kl},m}+g_{\underset{\vee}{lm},k}+g_{\underset{\vee}{mk},l}. \tag{6.19}$$

Narlikar and Ramji Tiwari used the equations (6.14)—(6.17) to obtain the interaction between the gravitational field of an isolated spherical body of mass m and a field (ϕ) of uniform monochromatic radiation. In the usual notation the effect of the gravitational field on the vector potential (F, G, H, ϕ) is given by

$$\Box^2 F+\Box\left(\frac{4m}{r}\phi\right)_{14}=\phi_1\left(\frac{8m}{r}\right)_{12} \tag{6.20}$$

$$\Box^2 G+\Box\left(\frac{4m}{r}\phi\right)_{24}=\phi_1\left(\frac{8m}{r}\right)_{22}-\phi_{11}\left(\frac{8m}{r}\right)_{1} \tag{6.21}$$

$$\Box^2 H+\Box\left(\frac{4m}{r}\phi\right)_{34}=\phi_1\left(\frac{8m}{r}\right)_{32}, \tag{6.22}$$

$$\Box^2\phi-\Box\left(\frac{4m}{r}\phi\right)_{44}=0, \tag{6.23}$$

where

$$\Box^2=\Box\,\Box \tag{6.24}$$

$$\Box=\frac{\delta^2}{\delta x^2}+\frac{\delta}{\delta y^2}+\frac{\delta^2}{\delta z^2}-\frac{\delta^2}{\delta t^2} \tag{6.25}$$

and the suffixes 1, 2, 3, 4 indicate differentiations with respect to x^1, x^2, x^3, x^4 respectively.

If the electromagnatic field is totally absent the equations (6.16) reduce to the contracted Riemann-Christoffel tensor being zero. This is so if g_{ij} is treated as the metric tensor. Recently Kurşunoğlu (1952) has worked out

the consequences of adopting s_{kl} as given by (5.45) as the metric tensor. Following Schrödinger he has found the mixed energy tensor of general relativity and he proposes in place of (6.16) and (6.17) equations of the form

$$R_{ik}=p^2(g_{ik}-s_{ik}), \tag{6.26}$$

$$R_{\underset{\vee}{\sigma}\beta,\,\gamma}+R_{\beta\underset{\vee}{\gamma};\,\alpha}+R_{\gamma\underset{\vee}{\alpha},\beta}=p^2(g_{\alpha\underset{\vee}{\beta},\gamma}+g_{\beta\underset{\vee}{\gamma},\alpha}+g_{\gamma\underset{\vee}{\alpha}\beta}). \tag{6,27}$$

p has the dimension (length)$^{-1}$.

Very little work seems to be going on in India on the unified theory. In 1938 Shabde gave an exposition of the general field theory of Schouten and van Dantzig. Bandyopadhyay (1951) has followed the latest field speculations of Einstein. The Einstein theory has yet to prove its physical worth. There is no indication so far how this theory can give a field of mass particles free of singularities. The postulates of the theory give no aesthetic satisfaction as there is considerable arbitrariness in the formulation (McCrea 1951).

Solving a mathematical problem is supposed to be like crossing a stream. The strategy is to build a temporary bridge. If after tremendous efforts one succeeds in building a bridge only to discover that it does not span the stream there would be frustration and disappointment.

As one reads Einstein's Autobiographical Notes published in 1949, one is struck by his persistent efforts, lasting over thirty-five years, to track the beast of mass-singularity to its lair since its triumphant appearance in Schwarzschild's solution in 1916. The beast was set running in 1938 in the formulation of equations of motion of the n-body problem by Einstein, Infeld and Hoffmann. In spite of all efforts it has not yet left the field theory for good. The search for a perfect field theory goes on. When the task is as big as that of the unified field theory and when crucial facts such as the quantum hypothesis are ignored the success that is reasonably possible cannot be quick in coming. In the face of all odds one may find inspiration in the thought, so well expressed by Whitehead:* "The fact that changes in our material universe can be predicted—that they are subject to mathematical law—is the most significant thing about it, for mathematical law is a concept of the mind and from the existence of mathematical law we infer that our minds have access to something akin to themselves that is in or behind the universe"

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INDIAN SCIENCE CONGRESS LUCKNOW

SECTION OF STATISTICS

President: H. SINHA, M.Sc., Ph.D.

Presidential Address.

WHITHER STATISTICS?

It is a matter of great pleasure and some surprise to me that I have been asked to preside over the Statistics Section of the Science Congress. I am old-fashioned enough to ascribe it, at least in part, to the old but now discredited theory of interest, *viz,* the reward of waiting. But I think it is chiefly due to the love the young workers in Statistics cherish for me, although I am now almost a back number. And it is on this that I rely for your indulgence in listening to these musings.

Separation of Statistics from Mathematics and the Consequences.

About two decades ago Professor Mahalanobis took Eve Statistics out of the ribs of Adam Mathematics in the Indian Science Congress. Many of us were at that time his humble associates. We little imagined at the time that this young lady would create so much trouble, showing her charms far and wide with an utter recklessness creating the "cussed" problem, not of the triangle, nor even of the quadrilateral, but of the polygon.

Different courses of study.

In the first place, she has invaded different teaching institutions, professional courses and even research laboratories, fundamental and applied. In my own University, that of Calcutta, she is not content with her own castle, the Post-Graduate Department of Statistics, but has made inroads into four other Post-Graduate Departments, —of Economics, of Commerce, of Pure Mathematics and of Applied Mathematics,—into the Department of Commerce twice, in the Day and the Evening Sections.

In the Indian Statistical Institute, Calcutta, theoretical and applied researches as well as sample surveys are being conducted on an extensive scale. There are, besides, no less than four different arrangements for training:—

(a) A two-year course for training in different branches of the subject;

(b) Specialised training to officers on deputation from the different States of India;

(c) A six-month course for the training of computers;

(d) A training course sponsored by the International Statistical Institute under the auspices of the U.N.O. for trainees from Middle, East and South-East Asia.

Four different examinations are conducted by the Indian Statistical Institute:—

(a) Training Section Examination;

(b) Computers' Certificate Examination;

(c) Statisticians' Diploma Examination;

(d) Statistical Field Survey Examination.

Statistics is also a subject for the examinations conducted by the Federal and State Public Service Commissions as well as by several professional bodies such as the Institute of Works and Costs Accounts. Other bodies in Calcutta such as the Calcutta Statistical Association promote the study of Statistics in some way or other. In other centres of learning throughout India the conquests made by Statistics are equally spectacular.

Increased Attention to Statistics in Business.

There has been recently a welcome change in the attitude with regard to Statistics in business circles not only in Calcutta but also elsewhere, as indicated by the setting up of such bodies as the Indian Society for Quality Control, the Bureau of Industrial Statistics and so on. This is also evident from the importance given to it in professional examinations and the setting up of Statistics Departments in business and industrial concerns.

And in Government Administration.

So far as Government is concerned, the recent change in its attitude is almost revolutionary. We all know Stamp's story about Indian Official Statistics[1]. Harold Cox, when a young man in India, quoted some official Statistics to a judge, who replied, "Cox, when you are a bit older you will not quote Indian Statistics with that assurance." Statistics which formed an unavoidable but almost a useless bye-product of administration in bygone days has now become the power house, so to say, for the execution of important measures of economic planning and social welfare.

Directions of Present Development.

It will be useful therefore to consider the recent developments of Statistics from four points of view:—

(a) Relationship beetween Statistics and Economics;

(b) Relationship between Statistics and Mathematics;

(c) Statistics in Business;

(d) Statistics in Government administration.

Statistics and Economics.

Ever since the days of the *Ain-I-Akbari*[2] the intimate connection between Economics and Statistics has been well known. It was not a mere accident that the Manchester Statistical Society was founded in 1833, the London (now Royal) Statistical Society in 1834, and Section F of the British Association (Economic Science and Statistical Section) in 1833. But even as late as 1877, Sir Francis Galton[3] in his anxiety to preserve the scientific purity of the British Association addressed to it "Considerations adverse to the Maintenance of Section F" in the following words:—

"It is believed that the general verdict of scientific men would be that few of the subjects fall within the meaning of the word 'scientific' ".

I may, I am afraid, be dubbed outmoded if I quote such views in these days of Econometrics. In justification I am tempted to recall some observations of such an eminent economist as D. H. Robertson[4]:—"An all embracing Social Welfare Function, whose maximum would indicate that all our decisions have been those which the Archangel Gabriel, or perhaps Uncle Joe Stalin, would have made in our place.......the allergia which I feel toward this vast parti-coloured Mathematical balloon ....". Fortunately, the beautiful balloon is still rising higher and higher up and there is no fear that it will ever be pricked.

"Quantifiable" but not Measurable.

A fine distinction has been sought to be drawn between what is "quantifiable" and what is "measurable", reserving the former expression for that which could be measured, if only we had a satisfactory unit of measurement. Data would be measurable when we have in fact such a unit. We leave to abstruse economists their headache over the distinction between "tweedledum" and "tweedle-dee",—their highly profound and entertaining discussion whether utility or satisfaction or economic welfare, or "Ecfare" (to quote Robertson once again), is "quantifiable" or "measurable", or neither. As statisticians we only stand aside so long as we are denied actual concrete measured data.

Highly Involved Multilateral Changes.

In making scientific appraisement of index numbers, time series, demand analyses etc., in Econometrics, we feel that however intimate the connection between Economics and Statistics may be, our present knowledge about it cannot be called satisfactory or adequate[5]. The need for replication inherent in Statistics is as great in Economic Statistics as in Agricultural Statistics. But we yet await the advent of a Fisher with his technique of Analysis of Variance, who will be able to analyse highly involved multilateral changes on a rational plan based on the theory of probability and correctly read the shifting sands of Economic Statistics. It is nearly 70 years ago, in 1885 to be exact, that Henry

Sidgwick[6] in his Presidential address on "Economic Science and Statistics" to the British Association, Aberdeen made the following observations, which are as true now as then:—"For duly discerning the various sources of error that impede the quantitative ascertainment of social facts, eliminating such error as far as possible and allowing for it where it cannot be eliminated—still more for analysing differences and fluctuations in the social quantities ascertained, and distinguishing casual from accidental variations and correspondences—there is needed not only industry, patience, accuracy but a perpetually alert and circumspect activity of the reasoning powers; nor is the statistician completely equipped for his task for discovering empirical laws unless he can effectively use the assistance of an abstract and difficult calculus of probabilities."

At the same time, one should not make a fetish of the calculus of probabilities, as pointed out by Austin Robinson[7]. It is true that linguistic abilities are essential for our ambassadors. But surely they have to be endowed with many other qualities if they are to prove equal to their important assignments. A Mathematician well up in the Calculus of Probabilities does not necessarily make a good statistician. For a statistician is neither a mere mathematician nor a mere collector of figures,—he must be something of both together with a strong common sense and a highly practical turn of mind.

Two Aspects of Economic Statistics.

I feel that there is a lamentable confusion with regard to the content of Economic Statistics not only in some professional courses but even in some of our University courses. There are I think two distinct aspects:—

(a) A training in general statistical techniques which a student is likely to apply in future in day to day business or Government administration;

(b) A training in fundamental theory he must have, if he is to apply the above techniques in order to arrive at correct and useful results.

It should be clear that the first is worse than useless unless it is supplemented by the second. For too often, Economic Statistics is taken to be merely a knowledge of the sources of official data, and even that without much knowledge about their methods of collection or presentation,—far less about their proper analysis and correct interpretation. So far as statistical methods are concerned, all basic theoretical considerations arising out of probability are usually conveniently ignored. This is all the more regrettable, for, on account of speed and economy in investigations, sampling is now being utilized to a greater and greater extent in place of complete censuses as of old. It should not therefore be overlooked that in the technique employed for such surveys and in the interpretation of results obtained, we cannot do without the theory of probability.

Statistics and Mathematics.

This brings us to the relation between Statistics and Mathematics. In the course of his observations on Dr. Wishart's paper on "Some aspects of the Teaching of Statistics", Professor Greenwood[8] pointed out:—

"In the heroic age of Statistics there were John Graunt with his shop Arithmetic and Edmund Halley, one of the great Mathematicians of his time. Both made contributions to the science, which would never be forgotten. Did anybody doubt who was the greater Statistician? Did many doubt that, without Graunt, Halley would never have done any Statistical work?"

But it may be respectfully urged that the second condition mentioned above cannot be satisfied unless there is training in the theory of probability, no matter whether we use sampling or not.

It is a trite but true saying that both etymologically and methodologically, a Statistician divides and rules. And for division, we require a pair of scissors, the two blades of which, *viz.*, adequate Statistical data properly collected on sound lines and their correct analysis based on probability theory are equally important. One is useless without the other.

Changing Populations.

I think it is necessary to point out that Economic Statistics is in a confused state to-day largely because the Mathematical background has been neglected. The old static conception of probability has to be somewhat modified into a new dynamic conception, if we are to achieve any substantial progress. For, it should not be overlooked that such problems arise not only in Economic time series but in many other fields from ballistics to atomic fission,—from cosmic rays to genetics. We have to face these problems of changing populations when our study relates to the rise and fall of epidemics, to the periodicity of sun spots and so on and so forth. Appropriate mathematical technique has not yet been fully worked out in respect of such continually changing populations.

An initial difficulty lies in the aggregation of populations large enough to permit sampling without careful circumspection. In the words of Bartlett[9]:

"We must find out how non-uniform such populations are, and the effectively uniform groups—the total number of susceptible persons in contact with an infected person, or the number of workers of one district, one age, one occupation and one disease—may invariably be small enough to make sampling questions permanently relevant to any theoretical and inductive conclusions which we may make."

Another effective limitation is offered by the smallness of movements

recorded in many series. For, the variation observed may be so small as to fall within the limits of sampling error. It will not then be generally possible to distinguish such cases statistically, and the main advantages due to sampling will be lost.

Fusion of Theory and Application.

If the truth has to be told, we await even now proper fusion between two old streams of Statistics, the Continental, based on games of chance leading to refinement of theory, and the English, based on factual data leading to development of proper techniques. "Departmentalism" in University courses and even in research institutions has militated against such fusion. There is a tendency to "stiffen" Statistics in the Mathematics Department and to "soften" it in other Departments. Even in research institutions, there is sometimes a lack of co-ordination between theoretical and applied work to the detriment of both.

Statistics and Business.

What is the role of Statistics in Business? Does it mean hanging up of Statistical charts and tables on all the four walls of the General Manager's room? Businessmen frequently and very justly complain that various Government Departments dump elaborate forms on their heads and demand at very short notice diverse data, which are in most cases not properly utilized by Government. Surely, businessmen themselves should not be open to the same charge of avoidable waste. Every figure which is produced, whether by Government Departments or by business houses costs money. Every figure, therefore, which performs no positive function should not be collected.

What then is the function which Statistics is intended to perform in industry and business? It is not merely quality control, nor productivity study, nor forecasting, nor costing by itself. The true purpose of Statistics in business houses is to serve as a check on, but not as a substitute for, the business man's judgment in whatever he does or thinks, and thus extends over all departments of the concern. In the words of Sir Geoffry Heyworth[10] in the course of his Presidential address before the Royal Statistical Society in 1949:—

"One begins with a judgment and one ends with a judgment. The purpose of figures is to come in the middle in order to make the judgment with which one ends more accurate than the one with which one began."

Wise words these, and they should remove not only the prejudice against Statistics which prevails among old-fashioned businessmen wedded to rule-of-thumb methods but also avoid much waste and many disappointments among young enthusiasts with their multi-coloured charts and diagrams.

Requisites of Business Statistics.

One of the methods for extending the use of Statistics in business on right lines is to make them simple, avoiding all complexities and refinements of an acedemic or general interest. They should be directly useful to the business concerned and regarded by it as remunerative. Any analytical study or development of theory must be left to other bodies such as Universities and research institutions.

Almost Unlimited Scope.

This will serve as a check on collection of Statistics merely for embellishment, in justification of the existence of the Statistics Department of the concern. For, there is almost unlimited scope for Statistical work in the interest not only of sound business research but also of the business itself. A factory, for instance, requires to be started in a far off country, say Ruritania, where Economic and political conditions are in a ferment, but which have nevertheless to be judged many years ahead, for the proposed factory is not likely to go into production for some time to come. The indicators, such as the number of persons detained without trial, the burden of rent on the peasantry, the proportion between industrial and non-industrial workers, may not be satisfactory, but have none the less to be carefully studied and conclusions arrived at to help the management in coming to a decision.

Index Number of Qualitative Changes.

Utilization of Statistics is always a matter of judgment, often requiring intuition. A judgment based on mere ratios may very often be wrong. Individual ratios may be inconsistent; a mechanical application of such ratios to matters of policy without studying how thay are interrelated may be incorrect. I can relate a story from my actual experience. About twenty years ago, I visited the United Dairies Ltd., one of the biggest multiple shops in England. I found that the statistician of the concern had worked out various ratios per gallon of milk sold for different cost items such as rent, wages, transport and miscellaneous charges. As the shops sold also other dairy products, their ratios per gallon were also calculated. If for any shop he found any cost item above the average for all the shops and any revenue item below the average, he insisted on that shop attaining the average figure, with the result that the averages themselves tended to improve for all the shops, raising the standard of efficiency all round. It was pointed out by me that these ratios varied so widely from shop to shop that they had to be estimated only after careful grouping, and, in the next place, if wages or rent paid were low for any shop, the ratios for other dairy products sold could not be high. In other words, the ratios were often inversely correlated among themselves. An all-embracing picture was therefore necessary, rather than a study of each ratio by itself. It is thus clear that for measuring the efficiency of any business concern, several indicators—

all of them not moving in the same direction—have often to be combined. Such composites in the form of what have been called index numbers of qualitative changes have been utilized in the U.S.A. for judging the adequacy of the school system, efficiency of hospitals etc.[11]

Statistics and Goverment Administration.

I have already indicated that there is increased attention paid to Statistics by Government,—not only in this country but also elsewhere. As pointed out by Simon Kuznets[12] in the course of his Presidential address delivered at the annual meeting of the American Statistical Association in December, 1949:—

"Whether the data are gathered in a deliberate search for information—as in our censuses—or as a bye-product of administrative activity; whether the social aggregate operates through the sovereign and authoritative organs of the State or through semi-voluntary bodies (trade associations, trade unions, professional societies etc.) the production of the data is a *social,* not an individual act." The end of *laissez-faire* even in advanced countries with the consequent intensified intervention of Governments in the economic life of the people everywhere has naturally called for more and better Statistics for the purpose of formulation and execution of economic policies and programmes.

Bane of Departmentalism.

This however has not been an unmixed blessing. The bane of "Departmentalism" has affected not only our Universities and research institutions as stated above, but also Official Statistics in this country as well as abroad. Every Department of Government must now have its separate "Economics and Statistics Division," no matter if this involves waste, duplication and lack of co-ordination,—no matter even if it involves some suspicion about the correctness of the figures collected by particular Departments in their own ways to prove their own cases. If the Central Statistical Office is not strong enough, such abuses cannot be lightly put down.

Nor in that case can Official Statistics inspire sufficient confidence among the people, who have in any case to foot the bill and also to suffer from the consequences of any unsound measure. It may be argued that people are at present not statistically minded. But in that case, our masters, the electors must be educated as quickly as possible in order that they may understand the implication of figures, if Governments really want to be broad based on popular will. For thus and thus only can democracy function in these days of controlled economy.

Closer Relation with Business.

What is wanted is that Government Departments handling Statistics should not stand aloof either from the people at large or from busi-

ness men. This is necessary not only because their interest and co-operation have to be secured but also because many pit-falls may thereby be avoided. Several amusing absurdities intrigued me when I worked for several weeks in the Board of Trade, Statistics Department, of the United Kingdom. An important Section was devoted to the Census of Production and because it formed a part of the Board of Trade, every concern was treated as a trade. Forms and schedules relating to a particular business were often sent to concerns, which had nothing to do with such business. There were protests, delays and long-range firing with angry and sometimes abusive letters, which could all be avoided if there was more intimate contact between Business and Government. This was twenty years ago and there must have been great improvement since then in the United Kingdom. In West Bengal recently there were two cases where recalcitrant (?) concerns refused to fill in the prescribed schedules for the Census of Manufactures. In the first case, a manufacturing concern could not supply the cost of fuel, because it was found out subsequently that it was not using coal purchased from the market but wood cut from a forest leased by it. In the second case, an electrical concern was not able to supply the cost of maintenance and repairs because diverse stores purchased at different times in big lots at prices prevailing at those times had to be utilized in driblets from time to time. If any figures were at all supplied, they would have been of doubtful value.

Internationalization.

It seems rather curious that side by side with this craze for independent Statistics by different Government Departments, there is a welcome tendency towards internationalization of Official Statistics. If the methods of collection and presentation are thus standardized, the data published by different countries will be strictly compairable. What is of still greater importance, their analysis anl interpretation will be facilitated, because the real nature of the data will no longer be a secret affair known only to the collecting agency.

Neglect of Theoretical Investigations.

This brings us to the greatest injury to our science wrought by the present craze for Statistics in the different Departments of Government. This has resulted in a large-scale diversion of Statisticians to Government work and consequent neglect of fundamental research. As stressed by Simon Kuznets, the present preoccupation with day-to-day problems militates against gaining a long-time perspective, a world-wide horizon and leisure for well-founded conclusions. According to him, Statistics should not mean merely the theory and practice of analyzing records of variance of a restricted, and more often than not, of a controlled type. He turns the table completely on his opponents with the following observations:—

"My reaction would be to avoid a debate on semantics, even though Statistics long meant a quantitative study of society, as the etymology of the very name reveals. What we call it does not matter; and if clarity may be attained thereby, let us christen the intellectual discipline I have been discussing with a new name—say Historical Arithmetic on the pattern of Political Arithmetic, one of its ancestors. So long as we understand by Historical Arithmetic the study and analysis that deals with quantitative records of historically bound processes for the eventual purpose of establishing tested generalizations; so long as we agree that the intellectual problems arising in such an effort are common to a wide variety of substantive fields of study, we shall be dealing with a body of methods of diverse application and a common core that justifies considering it a major field of scientific methodology." I feel very keenly that in our anxiety for "results", we may overlook this fundamental aspect. Surely the loss of a Newton or a Kelvin cannot be compensated by the royalties earned by an ingenious new patent!

Role of Statisticians.

There should I think be a clear-cut division of functions between statisticians and statesmen. The role of the former should be to give precise information in incisive quantitative terms with regard to the advantages and disadvantages of a proposed measure,—now and in the future. They should feel amply rewarded if they are able to do so to their own satisfaction. It should be left to the statesmen to decide whether to adopt that measure or not.

As pointed out above, Statistics can only aid judgment; it cannot and should not attempt to take the place of judgment. For there is often a conflict between the present and the future and among different interests. It is easy to show that there is a higher "Ecfare" immediately if the difference between skilled and unskilled wages is reduced. It is equally easy to demonstrate that such difference will lead to higher "Ecfare" in the long run. It is for the statesmen to decide whether the future is to be sacrificed for the present or *vice versa*. Similar conflicts arise in many other fields of Government Statistics, especially when we have to consider the interests of important groups, fully organized and intensely vocal, fortified with their own Statistics collected by their own institutions.

The Future.

Above all this clatter, when the present obscures the future, when a group thrusts itself out into the position of the entire nation, when a nation seeks to shut out the rest of the world, when Power and Preparedness have usurped the place of "Ecfare", we Statisticians should not lose heart, but go on steadily with our work in faith and hope,—in the words of Simon Kuznets, in "a belief in the existence of some order in

the seemingly chaotic jumble of history; in the demonstrability of such order in empirical terms: and in the ultimate social usefulness of the resulting body of tested theory."

List of References.

(1) Sir Josiah Stamp. "Some factors in Modern Life" (1929) pp. 258-259.

(2) A new edition of this classic is now available, revised by Jadu Nath Sarkar, the eminent historian, who, incidentally, is the author of a pioneer work on "Indian Economics", *viz.* "Economics of British India" (1913).

(3) J. R. S. S., 40 (1877) p. 468.

(4) "The Manchester School of Economic and Social Studies," 19 (1951), p. 142.

(5) A. R. Sinha's Presidential Address before the Statistics Section of the 38th Session of the Indian Science Congress, Bangalore, 1951, Appendix. The following observations by Simon Kuznets in his Presidential Address before the American Statistical Assoociation in 1949, quoted in J. A. S. A. 45 (1950) pp. 6-7 may also be noted in this connection:—

"As long as we recognise systematic, if you wish auto-correlated, patterns of temporal changes in historical series, and recognize them as quantitatively dominating, we cannot accept, until hypotheses of systematic changes have been thoroughly worked out, assumptions concerning variance that underlie the current theory of frequency distributions and sampling, assumptions that imply sufficient control to eliminate systematic major factors. These assumptions may be used towards the *end* of an analysis of time series, not at the beginning, just as the Statistical theory of normal and near-normal variance is used at the end of a controlled experiment, not at its beginning."

(6) Quoted by M. S. Bartlett in his paper on "Some Remarks on the Theory of Statistics" in "Transactions of the Manchester Statistical Society," Statistical Methods Group and Industrial Group, Session 1950-51, p. 12.

(7) "Economic Journal", 54 (1944), p. 267.

(8) J. R. S. S. 102 (1930), p. 552. The tendency to avoid Mathematics has probably reached its limit with disastrous results in "Statistics without Numbers" by F. Kafka (The City College, New York). New York. Lifetime Editions Inc. 1950.

(9) "Transactions of the Manchester Statistical Society", 118 (1951), p. 26.

(10) J. R. S. S. 113 (1950), p. 2.

(11) According to Croxton and Cowden's "Applied General Statistics", p. 645, probably the earliest index of the adequacy of the school system in the U.S.A. is to be found in the Russel Sage Foundation Circular No. 124 (1912) by L.P. Ayres, who subsequently revised it into "An Index Number for State School System", in 1920.

See also Ellen Winston's article on "Indices of Adequacy of State Care of Mental Patients" in "American Sociological Review," 3 (1938), pp. 190-202.

(12) J. A. S. A. 45 (1950) p. 2.

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SECTION OF PHYSICS

PRESIDENT: DR. N. R. TAWDE B.A. (Hon), M.Sc.,Ph.D., (Lond), F.Inst.P., F. A.Sc., F.N.I.

Presidential Address

MOLECULAR SPECTRAL THEORIES AND THEIR CONTRIBUTIONS TO COSMIC AND COMBUSTION PROBLEMS

I consider it a great privilege to have been called upon to preside over the Physics Section of the Indian Science Congress this year. I appreciate very much the honour my colleagues have conferred upon me and express my deep gratitude to all of them. The special field which I represent had perhaps no place in this honoured position for a long time and that probably may be the reason why the choice has fallen upon me. It will be, therefore, my endeavour to do justice to the subject in discharging the responsibility placed upon me.

INTRODUCTION

In recent years various theoretical and practical aspects of molecular spectra have come to play an increasingly important role in many special branches of physics and also in other branches of science, specially chemistry. For instance, the connection of intensity alternation phenomena of fine structure lines of bands with nuclear spin values and statistics, has inspired greatly the subject of nuclear physics. Extension of observations on molecular spectra of the gaseous state of a matrial to its liquid and solid state leads to conclusions about the nature and properties of these States of agregation and hance offers some clue to the nature of the liquid and the solid state. Collision processes involved in excitation have, to some extent, come to be interpreted in terms of the spectra of diatomic molecules, thought to be momentarily formed as *quasi molecules.* The knowledge of band spectroscopic data can be used to derive thermodynamic quantities like molar heat capacity of greater reliability than direct thermal measurements. Such spectral observations enable prediction of heat capacity of diatomic gases at high temperatures or of chemically unstable molecules like CH, NH, OH which are not accesible to direct thermal measurements. Thermodynamic functions derived from band spectra now replace more or less the values obtained by older experimental methods. Further, from the measure of intensities of band either in vibrational or rotational structure and with the help of the theoretical or experimental transition probabilities, it is possible to derive high temperatures, otherwise not accessible to usual methods. As a result of these developments molecular spectra and specially band spectroscopic temperature determinations, have in recent years received

important astrophysical and geophysical applications. Because of these, a relatively new and uncrowded field of *molecular astrophysics* has been opened up for study.

On the chemical side, besides the problems of chemical binding and valency, the results of band spectroscopy are being used through the knowledge of the existence of free molecular radicals and of the theoretical laws governing the absolute intensities of the spectra of such radicals, to draw conclusions about the mechanism of the disappearance or otherwise of these radicals or to put forth probable elementary chemical reactions in gases. From the spectral study of various radicals in chemiluminescence resulting from ignition processes in flames, certain chain reactions are postulated. This study has given rise to a definite branch of *combustion spectroscopy* bordering on chemistry and physics during the course of last few years. The elucidation of primary processes of photo-chemical reactions in gases is made possible through investigations on molecular spectra. Band spectroscopic data are also of great consequence in calculating the equilibria of gaseous reactions with accuracy. These are some of the channels along which band spectroscopic results are being increasingly directed.

The various phases of developments indicated above in the applications of the subject of molecular spectra cover too wide a scope. In none of these special fields, the progress of research can be said to have reached any way near the saturation point. In spite of this fact, to indicate even in a broad way, the recent progress achieved in all the special fields would be too ambitious a project for an address. It is, therefore, proposed to touch only those aspects which formed our principal lines of investigation at Bombay during the last few years. These relate to the theoretical and experimental transition probabilities in electronic band spectra of diatomic molecules, and the related topics of temperature determinations with special reference to astrophysical problems and combustion mechanism.

Molecular astrophysics concerns among other things with photometry of bands in relation to temperature determinations in the Sun, the stars, the inter-steller space, the planets and the earth's atmosphere. Such determinations follow from the knowledge of transition probabilities or for that matter, of intensity distributions among the vibrational states of an electronic transition or among individual rotational lines of a given vibrational transition. Photometry as applied to bands is also of use in the study of molecular abundance in variable stars apart from the atomic abundances. Measures of relative intensities of two absorption bands in a star combined with the knowledge of their relative transition probabilities enables information to be obtained regarding the opacities of the stellar atmosphere at two wave lengths. Importance of accurate photometry of laboratory sources of astrophysically important molecules like Al0, ZrO, etc. is being felt to assign possible temperatures to stellar bodies in which they occur. Further, the problem as to how the dissociation processes at different atmospheric levels affect the resulting band intensities, derives its solution from precise photometry of bands. But in problems of experimental spectrophotometry great caution has to be used, especially when it is a question of verifying theoretical concepts.

1. Band Photometry

The experimental photometric technique as applied to bands has undergone successive refinements since the year 1930. The progress went hand in hand with theories in the earlier period, but later made rapid strides with the

introduction of new devices. The old practice of visual methods and density blackenings has now given place to (i) photographic emulsion with proper account of its varying sensitivity and calibration of the spectrum in terms of standard energy units and (ii) special electrical devices, such as photomultiplier. The method of spectral photography is the simplest to apply and convenient too, for extensive spectral regions such as those of electronic band systems. This is specially so because of available wide sensitivity of emulsions. However, on account of many band lines to be subjected to measurement or many bands to be accurately computed for contour areas, much labour is involved and errors are likely to creep in. The relative advantages and disadvantages of photographic technique involving step-slit, logarithmic sector, step-wedge or neutral tint-wedge have been described in a number of standard books or original papers dealing with the subject of photometry of bands. The methods adopted by Ornstein and others of Utrecht School[1], Elliott[2] Johnson and Tawde[3], Tawde and Patankar[4] and others [5] are now pretty well known in this field.

There appears to be a trend, of late, towards using direct methods involving the use of photo cell in conjunction with a sensitive galvanometer and current amplifying devices. These are further giving place to photo-multiplier. The technique of such methods can very well be studied from Forsythe[6], Tawde and Unvala,[7,8] Dieke[9] and others[10,11]. Because of its recent growth, photomultiplier has not been much adopted for band photometry, though for line insensity measurements it is more frequently adopted especially when low fluxes of radiation have to be measured.

We shall now examine the successive developments on the theoretical side, with a view to form some idea of the present position of the subject.

2. Transition Probabilities

(i) *Elementary Franck-Condon Principle.*

Franck[12] first suggested the mechanism of dissociation of a molecule by a photon. With this as basis, and taking help of postulates of old quantum theory, Condon[13] developed Franck's ideas quantitatively. He made the following fundamental assumptions to put forth his theory of transition probabilities:

(i) that an electronic transition takes place so rapidly and in such a manner that the instantaneous internuclear distance and nuclear kinetic energy are unchanged;

(ii) that an electronic transition is most likely to occur when the nuclei are in their extreme positions, either of minimum or maximum separations.

With the knowledge of these assumptions and the course of $U(r)$ curves for the electronic states involved in the transition, the various favoured transitions could be predicted. The theory thus indicates only the most probable transitions and not the whole range of possible transitions. These transitions identified by maximum intensities lie along a parabolic path in the well known (Deslandre's) double-entry tables.

The earlier attempts to test the elementary Franck-Condon Principle were made more or less with semi-quantitative measures of band intensities. These data besides confirming the expected parabolic distribution served as a guide in identifying the band systems. Rigorous quantitative estimates of band intensities to put the principle to test were made by Johnson and Tawde[3] in C_2 (Swan) bands, though earlier, Elliott[2] measured the β-bands

of BO to verify the more advanced aspects of the theories, to which reference will be made in a later section. The transition probabilities arrived at by Johnson and Tawde were found to agree in a most general way with the Condon predictions of most probable transitions. There was however, some evidence of transition probabilities varying with methods of excitation.

Johnson and Dunstan[14] later used BeO bands to study the principle and came to the same conclusion as Johnson and Tawde. Tawde[15] and collaborators[16,17,18,19] pursued work on these aspects by taking C_2, N_2 (IIP), CN(violet), AlO, BeO, etc. under a number of varied conditions of flames, arcs, sparks and discharges (50 cycle, h.f.) and succeeded in showing that the Franck-Condon principle was in general obeyed except for a few anomalies characteristic of the conditions of the sources and the molecules. Of the several molecules studied, N_2 bands provided anomalous features. Elliott and Cameron[20], however, found from the intensities in N_2 (IP) that conditions of excitation caused no change in the distribution.

Potential energy functions: Tawde showed that the results in certain molecules satisfied Franck-Condon principle somewhat better, if Rydberg's[21] form of potential energy relation is used instead of the usual Morse[22] expression. This was the case for N_2 (IIP) and some data on C_2 (Swan). Johnson and Dunstan[14] later confirmed this observation in BeO bands. Lately, the subject has been further explored by Gopalakrishnan[23] in our laboratory, while studying C_2 (Swan) bands and the workability of Hulbert-Hirschfelder[24] expression in it, in addition to Morse's and Rydberg's. His findings are that this expression gives a much inferior fit with the ob served intensity locus, though Gaydon has maintained the superiority of this expression in many cases. According to Gopalakrishnan, the discrepancy is to be traced to the fact that the expression is actually a correction of the three-parameter Morse function by the use of two more constants. This correction does not improve the form of the curves in the right direction and seems to be too much exaggerated as far as its applicability to the case studied by the author is concerned.

Thus it appears that any theory that attempts to predict the right course of maximum transitions has neccessarily to take account of the proper function satisfying the nuclear potential energy of a molecule over a given electronic state.

A number of other useful functions besides those attempted have been proposed by different authors, Dunham, [26], Lotmar[27], Manning and Rosen[28], Poschl and Teller[29], Hylleras[30], and Coolidge, James & Vernon[31]. Though they have been reviewed and compared among themselves by Hulbert & Hirschfelder[24], their actual application to specific molecules is not known. In all these mathematical expressions, use of derived molecular constants is made to obtain the curves. These constants according to Rydberg[32], are subject to the tenability of the assumption that the vibrational energy levels can be adequately represented by a single rapidly convergent power series of the usual form in $(v+\frac{1}{2})$. This is not always the case as sometimes there are definite signs of an abrupt change in the rate of convergence, in which case the vibrational energy levels have to be represented by even two different power series. Therefore, in order to eliminate errors consequent on using the constants of a single power series, it is desirable to use the levels themselves, rather than some derived formula for these levels. Rydberg[32] & Klein[33] have developed, in this direction, methods which have been used with success

by Rosenbaum[34] and by Almy & Beiler[35] to draw potential energy curves. In spite of the advantages claimed, the methods have their apparent limitations and have remained in disrepute.

In addition to the normal Condon parabola, presence of subordinate parabolas came to light as a result of the investigations of Herzberg[36] on bands of P_2, Almy and Kinzer[37] on As_2, Jenkins and Rochester[38] on AgCl and Gaydon and Pearse[39] on RbH. They were explained by a more comprehensive process of vibrational eigenfunctions by Gaydon & Pearse, to be discussed later.

(ii) *Condon's Wave Mechanical Treatment.*

This qualitative formulation of elementary Franck-Condon principle on the basis of old quantum theory was given a quantitative refinement through wave-mechanical treatment by Condon[40] himself in a later paper. As per new quantum mechanics, the intensity of a spectral line is the product of electric moment and the wave functions of the initial and final states, integration being carried over all co-ordinates of electrons and nuclei. Extending this idea to the electron-vibration transition, the measure of transition probability and for that matter, the intensity either in emission or absorption, is found to be proportional to the square of overlap integral which is the product of vibrational eigenfunctions of the two states involved and expressed as

$$\int \psi'(r)\psi''(r)dr \qquad \ldots \quad (1)$$

The value of the overlap integral being dependant upon the form of the potential energy curves and their relative positions, that is separation of their minima in the upper and lower states, some typical intensity distributions characterised by very open, broad, narrow or single-limbed parabolas become apparent. Thus form the wave-mechanical treatment of Condon, essentially the same results follows as from the elementary concepts of Franck-Condon principle outlined above.

Both these theoretical concepts viz,. the old quantum theory as well as wave mechanics bring out only the broad features of intensity distribution and allow only qualitative or semi-quantitative tests to be made as it is assumed that the effects of the intermediate maxima and minima of the oscilator eigenfunctions cancel out. Actually for some relative position of the potential energy curves, there may be unusually large intensity far away from Condon branches or unusually lower intensity close to it.

(iii) *Hutchisson's Theory I.*

Using Condon's wave-mechanical ideas, Hutchisson[41] gave an analytical treatment to evaluate the overlap integral on simple assumptions of (1) linear oscillator eigenfunctions and (2) symmetry of molecule. His final composite expressig on for the probability of transition $P_{v'v''}$ is given by

$$P_{v'v''} = \int_{-\infty}^{+\infty} (N_{v'} N_{v''})^{-1} \; e^{-n^2/2} \; e^{-(\alpha\eta+\delta)^2/2} H_{v'}(\eta) H_{v''}(\alpha\eta+\delta)\, d\eta$$

$$= C_3 \frac{(v'!\, v''!)^{1/2}}{2^{(v'+v'')/2}} \cdot \sum_{l=0}^{v' \text{ or } v''} \; \sum_{i=0}^{\substack{(v'-l)/2 \\ (v'-l-1)/2}} \; \sum_{j=0}^{\substack{(v''-l)/2 \\ (v''-l-1)/2}} \cdot a_{2l} \cdot b_{3i} \cdot c_{2j}\, d_{v'-2i-l} \cdot e_{v''-2j-l} \qquad \ldots \quad (2)$$

where

$$C_3=\left(\frac{h}{2\pi^2\,\mu\nu'_o\,\alpha(\alpha^2+1)}\right)^{1/2}\cdot\;e^{-\delta^2/2\,(\alpha^2+1)}\;,\;a_{2l}=\frac{1}{l!}\left(\frac{4\alpha}{1+\alpha^2}\right)^l$$

$$b_{2i}=\frac{1}{i!}\left(\frac{1-\alpha^2}{1+\alpha^2}\right)^i\;,\qquad C_{2j}=\frac{1}{j!}\left(\frac{-(1-\alpha^2)}{1+\alpha^2}\right)^j$$

$$d_{v'-2i-l}=\frac{1}{(v'-2i-l)!}\left(\frac{-2\alpha\delta}{1+\alpha^2}\right)^{(v'-2i-l)}$$

$$e_{v''-2j-l}=\frac{1}{(v''-2j-l)}\left\{\frac{2\delta}{1+\alpha^2}\right)^{(v''-2j-l)}\qquad\text{and}$$

$$\alpha=\left(\frac{\nu''_o}{\nu'_o}\right)^{1/2}\quad\delta=0.1221(r'_o-r''_o)(\nu''_o\,M)^{1/2}$$

available from molecular constants.

This expression can be used to arrive at numerical measures of absorption band intensities on a relative scale. In emission it can be used to compare bands of a progression originating at a given v'.

The first attempt at computation of transition probabilities by the above expression was made by Hutchisson himself in the case of absorption bands of Na_2, K_2 and I_2. In general, a good agreement with available experimental results was found. He failed to obtain, however, the same type of agreement for emission bands in the only system studied by him, viz,. the $3^1B\rightarrow2^1g$ transition of H_2. He has, however, indicated that the degree of disagreement found at (0,1) and (2,1) bands is reduced if the calculated transition probabilities for these bands are substituted respectively by that of (1,0) band and (1,2) band.

Elliott[2] made accurate intensity measurements in β-bands of BO and later used these results to verify transition probabilities by applying Hutchisson's theory I. But his rigorous test of the theory was, however, on the α-system of the same molecule in which the experimental data was obtained by two methods, using in one a lamp calibrated by a thermopile and in the other, an optical pyrometer. The values in both the cases though differing from each other, were related by a constant factor and thus could be expressed on a common relative scale. These when compared with calculations by assuming harmonic oscillator gave agreement with experimental results over v'' progression corresponding to only $v'=0$ and 1. For progressions of higher v', there was considerable disagreement. Similarly in the β-bands of BO, Elliott found also tolerable agreement between theoretical and experimental transition probabilities, in spite of the partial nature of the system available within the spectral region investigated.

Almost simultaneously, Price[42] computed theoretical transition probabilities of some band system of hydrogen using Hutchissons' theory I by making a number of variations in it. He found only a rough agreement of experimental results with predictions on the basis of eigenfunctions of harmonic oscillator.

Later Tawde and Patankar [43] used Hutchisson's theory I to derive the transition probabilities in bands of N_2 second positive system in emission and compared the same with accurate measurements, using integrated intensity under band contours. The expected satisfactory agreement was

not found for relative intensities in v'' progressions, in spite of the use of integrated values. With higher sequences and with higher member of sequences, the degree of disagreement showed progressive rise. It occured to Tawde and Patankar to examine the nature of agreement so found by interchanging the quantum numbers, from (x, y) to (y,x) acting on the faint indication given earlier by Hutchisson[41]. They found that by this procedure there was considerable improvement in agreement over the earlier comparison, even though there was still a wide gap between the theory and experiment especially in bands of higher quantum numbers.

Patel[48] in our laboratory computed the transition probabilities in C_2 (Swan) system and by comparing them with experimental results on oxy-coal gas flames, confirmed in general the conclusion of Tawde and Patankar as regards the partial validity of Hutchisson's theory.

Brown[44] carried out the experimental study of intensities in the series of Na_2 in fluorescence and compared the results with derivations from Hutchison's formula. Having failed to obtain closeness of values, he corrected Hutchisson's formula of harmonic oscillator, by inserting the constants proper to each vibrational level, instead of using the same eigen-functions in every case. Such a process resulted in giving much better qualitative agreement with experimental values, than Hutchisson's uncorrected expression.

Langstroth[45] from his intensity data on nitrogen (IIP) in emission has found Hutchisson's theory to give only approximate agreement with his results. In general the theory was inadequate to meet the actual situation in emission. He therefore, suggested the inclusion of excitation mechanism by electron impact, in Hutchissons transition probability considerations. This development has been treated in a subsequent section.

It is the expectation of theory, as Wehrli[46] has shown, that when harmonic eigenfunctions are used in cases where the equilibrium nuclear separations coincide, but vibrational frequencies are different, only the transitions with even(Δv) are permitted and those with odd (Δv) have zero intensities. Such pheomena result in giving subsidiary maxima at even (Δv) which have been verified by Wehrli in GaI and InI where the predisposing conditions are approximately satisfied.

In 1932, Wurm[47] calculated the transition probabilities in C_2(*S*wan) and CN (violet) system, using Hutchisson's theory I. Later Patel[48] in our laboratory carried out theoretical calculations of band intensities in C_2 (Swan) system. Independently, McKellar and Buscombe[50] also did these calculations for both C_2 (Swan) and CN (violet) systems for purposes of determining the temperatures in R-type stars. But curiously enough they could not confirm the calculated values of Wurm[47] even by using the same molecular constants. In the meanwhile, King[51] reported some experimental results on the Swan system which he subjected to scrutiny in the light of the calculated transition probabilities of McKellar and Buscombe, and of experimetal results of Johnson and Tawde[3]. Access to these results of McKellar and Buscombe, through Kings' paper led Tawde and Patel[49] to report the earlier thesis results of Patel on theoretical transition probabilities of Swan system to show certain anomalies existing between their values and those of McKellar and Buscombe. These have now been cleared by McKellar and Tawde[52] as due to different molecular constants being used in the calculations, Tawde and Patel having used constants which are closer to the recent revised data of Phillips[53] on the Swan system. Incidentally, they have also shown that transition probabilities are highly sensitive to minute changes in the

constants, especially (Δr), the difference in internuclear distance. Thus the need of obtaining more precise data on the molecular constants by accurate rotational and vibrational analysis of bands is to be emphasised. The cause of large disparity between the values of Wurm [47] and the more recent data is not easily understood.

The ocmparison of transition probabilities with experimental results revealed from the study of Tawde and Patel's results that both in v' and v'' progressions, the disparity between the two increases systematically with the increasing (Δv). King has noticed a similar tendency but not so systematic as in Tawde and Patel's findings.

From the nature of evidence presented above, it can be said that the quantum mechanical concepts of Hutchisson's first theory were generally in the right direction, but they proved inadequate to meet the real situation in electronic band spectra, as seen from the many suggestions for improvement to bring the theoretical predictions in line with experiments, by right choice of potential energy function, the vibrational energy expressions or by the available refinements in the molecular constants.

(iv) *Hutchisson's Theory II.*

As anharmonicity is a characteristic feature of electronic band systems, and as the experimental results also have been shown to be in conflict with theoretical transition probabilities for higher quanta, derived from approximations of harmonic oscillator, a new approach to the subject seemed inevitable. In order to correct for the deviations from linear oscillations Hutchisson [54] expressed the nuclear potential energy in the form of three term power-series and used Schrodinger's perturbation theory to construct the complete wave function; and hence the intensity amplitude $I_{v'v''}$ as

$$I_{v'v''} = \sum_{k=v'-4}^{v'+4} \sum_{j=v''-4}^{v''+4} . C_{v'k} . C_{v''j} . I_{kj}^{\circ} \tag{3}$$

where $k=v'-4$ and $j=v''+4$.

This contains in general 81 terms and requires long calculations. But if one confines to absorpition bands, the intensity amplitude reduces to the following simpler form

$$I_{v'v''} = \sum_{k=v'-4}^{v'+4} . C_{v'k} . I_{kj}^{\circ} \tag{4}$$

In this only 9 terms are involved and hence the prediction of absorption intensities becomes a workable proposition by this expression.

This theory has rarely been used. The only serious attempt on record is that of Hutchisson himself, who calculated the transition probabilities for absorption bands of hydrogen. As is to be expected the agreement with experimental observations showed considerable improvement over that shown by earlier theory, based on harmonic oscillations. The high values given by the first formula were appreciably reduced with the use of the new expressions. But the power-series expressions, even when carried to two approximations, gave reliable results only over a limited lower vibrational quanta. With the help of wave functions derived from Morse energy expression, Hutchisson

obtained still better agreement not by the direct integration of the analytical expression incorporating this function, but by the effect produced on values resnlting from integration carried out graphically. This led him to suggest that Morse expression probably served much better and reached reality much earlier than a 3-term power-series expression for bands in the region of higher quanta. Beyond this, the use of 81-term or even 9 term expression is not hnown.

The consideration of anharmonicity effect in other analytical ways is due to Price [42] who used (1) usual Morse expression in harmonic oscillator eigenfunction of Hutchisson theory I, (2) a modified Morse function in the same and (3) entirely new eigenfunctions. These computations were tested by Price[42] from the expressions derived by Davidson[42] for some absorption bands of hydrogen transitions.

$$3d^1\pi_b \rightarrow 2p^1\Sigma$$
$$3p^1\pi \rightarrow 2s^3\Sigma,\ \alpha \text{ bands}$$
$$4p^3\pi \rightarrow 2s^3\Sigma, \beta \text{ bands} \qquad \ldots \quad (5)$$

His conclusions as regards the relative efficiency of the methods of bringing about anharmonicity are:

(1) The new eigenfunction brings much better improvement than the use of modified Morse expression in the harmonic oscillator eigenfunction.

(2) This latter is still better than the usual unmodified Morse expression in the same eigenfunction.

(v) *Dunham's Considerations.*

While studying the possible effects of a difference in nuclear mass on the probabilities of transitions derived from Hutchissons' theories, Dunham[55] has found that such effects are generally small. This. he has considered to be due to electric moment not changing as rapidly as eigenfunctions. Hence according to him the theoretical deductions of Hutchisson[41,54] in the case of harmonic or anharmonic oscillator need not be restricted to symmetric molecules for lower quantum numbers, but can be applied equally to a symmetric molecule. Further he has detected that the constant C_3 of intensity integral for harmonic oscillator as occuring in Hutchisson's theoretical derivation, is apparently in error, its correct value being

$$C_3=[2/\alpha(1+\alpha^2)]^{\frac{1}{2}}.e^{-\delta^2/2(1+\alpha^2)} \qquad \ldots \quad (6)$$

However, with this correction the relative intensities are not affected as its value is the same for all transitions. Hutchisson has later confirmed this correction of Dunham.

The applicability of the above conclusion of Dunham can be tested by reference to the results of Elliott[2] on α and β-bands of BO, where there is as symmetry in the two nuclei as per Hutchisson's considerations. Still the results are found to agree with experiment nearly to the same extent as in perfectly symmetric molecules. The other spectrum of asymmetric molecule which has been the subject of investigaions is the CN (violet) system, whose transition probabilities have been computed by McKellar and Buscombe[50]. Nature of their agreement with experiment is of the type found for symmetric molecules. Restriction of Hutchisson's theory to symmetric molecules should not therefore be very strict as first proposed by Hutchisson

and that there is considerable justification in the assumption that electric moment does not change as rapidly as eigenfunction. However, the other limitation viz. restriction of Hutchisson theory I and of theory II (as far as it was tried) to relatively small quanta cannot easily be relaxed, in the face of the available experimental observations.

Experimental results of Tawde on CN bands when compared with McKeller and Buscombe's theoretical values indicate in general the same conclusion. The observations on AlO and BeO bands by Tawde and Trivedi[18] and Tawde and Hussain [19] are still awaiting test from standpoint of theory of Hutchisson and the specific considerations of Dunham about asymmetry. Other asymmetric molecules need to be investigated for verification of these aspects.

(vi) *Langstroth's Theory.*

The limitation of the applicability of Hutchisson's theory I to only bands of a given progression arising at v' in emission, was sought to be removed by Langstroth[56] by suggesting a way of getting the relative estimates of distributions in the initial states. Considering the band system to be excited by electron impact, such that contributions to any v' state are due to excitation from absolute $v=0$ level of the ground state or X state, Langstroth calculates the excitation probability for a level v' of the initial state by the expression of intensity integral of Hutchisson's theory I as $P^2{}_{0,v'}$. The assumptions made by Hutchisson for this to hold are: (1) exciting electrons have practically no effect upon comparatively very massive nuclei (ii) because of the rapidity of electronic re-arrangement in exicitation, the nuclear coordinates remain unchanged during transition, (iii) with suitable choice of experimental conditions, the majority of molecules are in the ground state $X,v=0$, (iv) the contributions of combination and cascade effects to the population of the initial levels are considered negligible.

The excitation probability multiplied by the emission probability $P^2{}_{v'v''}$ calculated numerically as per Hutchisson's expression of intensity integral then gives complete intensity

$$I_{v'v''} = C.\ \nu^4.\ P^2{}_{v'v''}(r)P^2{}_{0,v'}(r) \qquad \dots \quad (7)$$

of any band.

This expression should provide correct results, if the assumptions of Langstroth are justified. They can be tested by seeing whether band intensity ratios maintain constancy with change in excitation voltage. If they do, then by comparison with experiments, the final expression for complete intensity furnishes a test of entire theory of Hutchisson, along with Langstroth's theoretical considerations based evidently on only harmonic oscillator eigenfunctions.

Langstroth relies for verification of his theory on the fulfilment of the assumptions of excitations of band systems by electron impact. In this connection one has to see how far electron velocities are able to alter the relative intensities in a band system. For this purpose, Langstroth excited (0,2), (1,3) and (2,4) bands of the IIP system of nitrogen by electrons with accelerating potentials between 14 and 160 volts and found that the ratio of the intensities of these bands remained constant when accelarating potentials were more than 30 volts. Below this, the ratio varied. Such observations were extended to nine more bands of the system by Langstroth and

in general the conclusion was the same, viz, that relative intensities were unaltered by potentials greater than 30 volts. Subjecting the experimental conditions to this criterion the transition probabilities were investigated as well as found theoretically in nitrogen IIP system.

The product of the two probabilities, i.e. of exitation and emission gave the complete intensity, which, when compared with experimental results did not give, however, the expected close agreement, through there was improvement over the earlier results derived by considering emission probability alone. In fact the agreement was only approximate. He assigned the cause of this discrepancy partly to the neglect of anharmonicity in theory and partly to the want of accurate intensity data. The first cause is no doubt genuine. As regards the second, comparing his theoretical complete intensities with the results of Tawde on nitrogen IIP system under different methods of excitation he showed that even along v''-progressions, the relative transition probabilities of Tawde were far from those of theory. He was not prepared to attribute this to the failure of his theory but for the limitations on the acuracy of Tawde's experimental values, owing to peak intensity data instead of integrated intensity results.

Pursuing the problem further, Tawde and Patankar [43] subjected the IIP system to the integration methods of photographic photometry and obtained precise measures of relative intensities for 21 bands, 9 more than the number attempted by Langstroth. They also calculated the complete intensities by introducing Langstroth's excitation probability and concluded from their comparative study that approximate character of agreement examined by Langstroth earlier, did not materially alter towards improvement. But relatively there was closer approach when theoretical values are taken with interchanged quantum numbers, as in Hutchisson's theory I.

The failure of Langstroth's considerations apart from the neglect of anharmonicity which is common to both excitation and emission, to effect expected improvement has been considered by Tawde and Patankar to be due to exicitation probability factor not taking into account the true state of affairs. It may be that some levels higher than $v=0$ in the ground state are also populated in which case, they may also contribute to the upper state. Further there may be a possibility of some contributions to these populations by combination and cascade effects, which are assumed to be absent by Langstroth in his treatment. Then again there is Zener's [57] perturbation effect which cannot be ruled out altogether.

On the criterion of the particular accelerating potential of electrons needed to validate the applicability of Langstroth's theory, the evidence is conflicting. While Langstroth is inclined to fix the accelerating potential of electrons above 30 volts to maintain constancy of relative intensity values, Hermann[57a] finds from his results no such dependability of intensities on on exciting voltage.

Thus in general the position remains the same as prior to introduction of anharmonic oscillator eigenfunctions by Hutchisson in his theory II.

(vii) *Gaydon & Pearse Numerical Integration Method.*

Quite distinct from the evaluation oftheoverlap integral $\int \psi_{v'}(r)\psi_{v''}(r)dr$ by analytical approach in the manner discussed so far, Gaydon and Pearse[58] have suggested the method of numerical integration of the overlap integral, involving the distortion of the harmonic oscillator functions to take account of anharmonicity.

The authors obtain the normalised wave function of the harmonic oscillator in the form

$$R_{v'} = \frac{1}{d}\sqrt{\left(\frac{1}{2^{v'}\,v!}, \quad \frac{1}{\sqrt{\pi}}\right)} \quad e^{-\frac{1}{2}(x/d)^2} \cdot H_{v'}\left(\frac{x}{d}\right) \qquad \ldots \quad (8)$$

in which $$d^2 = \frac{h}{4\mu^2 c\mu w_e} \text{ and } x = (r - r_0)$$

Writing $x/d = s$, the Hermitian polynomials are given by

$$H(x/d) = H(s) = (-1)^u . e^{s^2} . \frac{d^u}{ds^u}(e^{-s^2}) \qquad \ldots \quad (9)$$

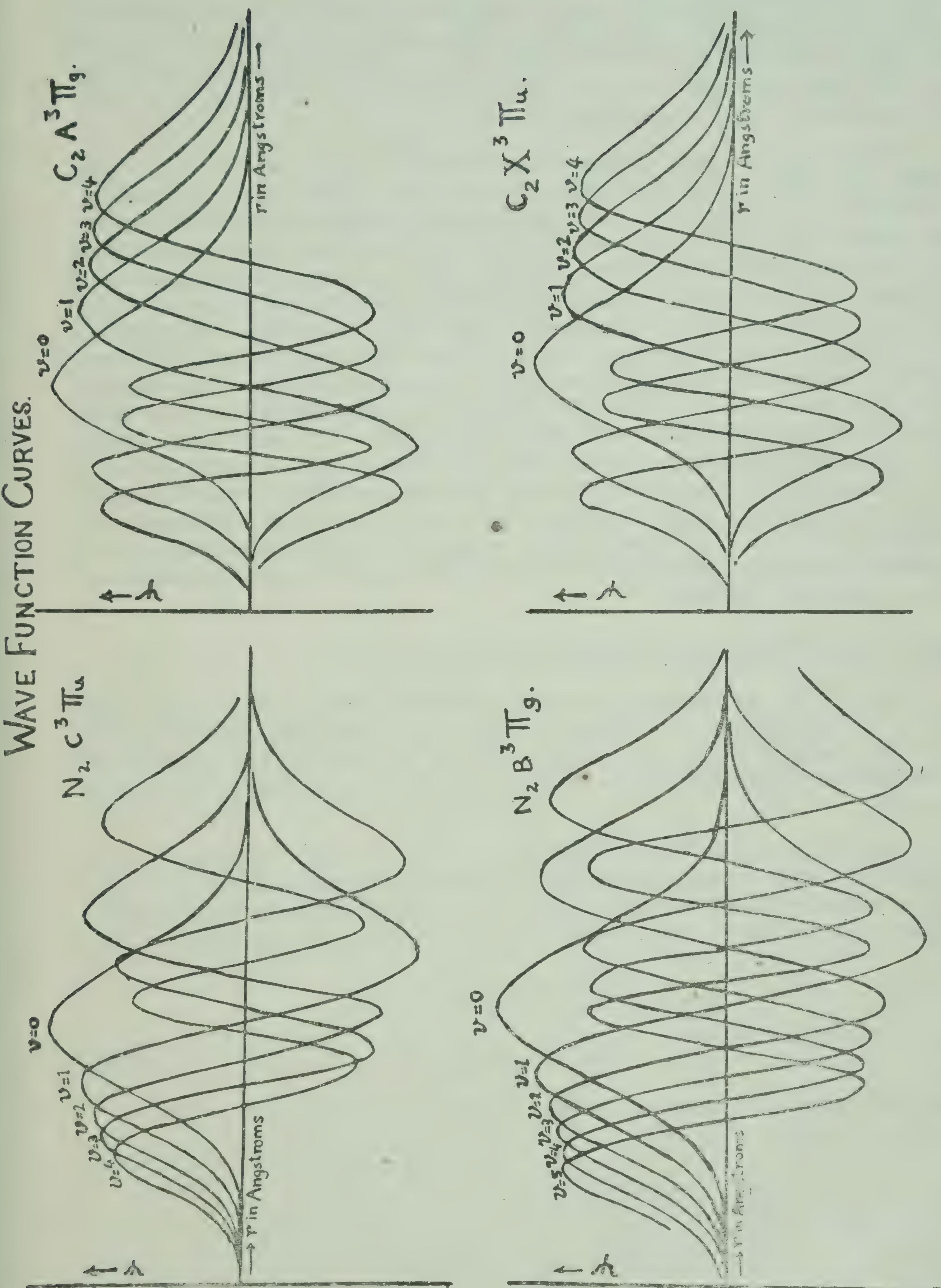
Gaydon and Pearse have evaluated $R_{v'}$ with the help of the two equations for various values of r and drew wave function curves for the initial and final states. These are then transformed to the wave function of the anharmonic oscillator by means of the experimentally justified Morse expression. With the help of these (No. 8, 9) the numerical integration of the overlap integral is carried out by the process outlined by the authors. In this method the effects due to distortion if any, on normalisation, are neglected.

The earlier work on the application of the method of Gaydon and Pearse was in the nature of merely verifying the broad features of band systems such as the existence of subsidiary parabolas inside main Condon parabola and identification of observed bands or expecting new ones.

Probably the first attempt at rigorous verification of intensities quantitatively by the numerical integration method of Gaydon and Pearse, is due to Laud [59] in our laboratories (Vide Fig. 1(a) for eigenfunction curves.)

Laud who studied the C_2 (Swan) bands in the flames of ethyl alcohol set before him the twin object of examining intensity distribution as a function of the excitation conditions and of comparing the available theoretical transition probabilities derived from Hutchisson's intensity integral with the present method of Gaydon & Pearse. He concluded that (a) the weight of agreement is more in favour of Hutchisson's theory than the method of numerical integration, such a conclusion being independent of the quantum number of bands and (b) over four air-fuel ratios, corresponding generally to stabilized flames, out of the eight examined, the observed distribution did not alter sensibly beyond limits of experimental errors.

Laud is inclined to say that this behaviour may result from the very rough approximations made for approach to anharmonicity condition and the consequent crudeness of the method, which brings in large departures in transition probabilities. There is no doubt a tendency in the method to shift the transition probabilities (as derived from Hutchisson's theory I) towards the experimental values but the anharmonicity correction apears to be too much exaggerated, so much so, that the magnitude of the shift goes far beyond the required limit. Probably the various approximations involved viz. the distortion of Hermitian polynomials, neglect of normalisation effect, etc. are responsible for the large shift which is much in excess of what is required to obtain the proper wave function for satisfying anharmonicity.


WAVE FUNCTION CURVES.
$C_2\ A^3\Pi_g$.
$C_2\ X^3\Pi_u$.
$N_2\ c^3\Pi_u$
$N_2\ B^3\Pi_g$.
v=0
v=1
v=2
v=3
v=4
v=5
r in Angstroms
h

(a)

FIG. 1.

(b)

On this point of anharmonicity one is not, however, sure, whether it is really playing a part as far as the role of this method (numerical integration) is concerned. If it was so, there should have been closer agreement between this method and Hutchsson's theory I, at least for bands of lower vibrational quanta, if not for higher. But such is not the case, for the difference between the two, even for bands of lower vibrational quanta, is too large and it does not show any systematic change towards improvement with increasing quantum numbers along progressions.

Correction for small change in normalisation factor and for the slight shift of the central peak of the wave function curve in the distortion process, foreseen by Laud, has in fact, been independently made by Pillow[59] recently. She applied this procedure to calculate the theoretical transition probabilities for C_2 (Swan) CN (Violet) and N^+_2 systems. For verification with experiment, she has used the results of King [51] and 5 independent sets of values of Johnson and Tawde[3] on C_2. Comparison with other theoretical calculations, viz. of McKellar and Buscombe [50] and of Tawde and Patel [49] have also been made. Similarly in the CN (Violet) system she has verified her experimental data with similar results of Tawde[16], Ornstein and Brinkman[60] and the theoretical one with McKellar and Buscombe's. For N_2^+ bands comparisons have been made with experimental sets of Herzberg[61] and Bates[62] and with theoretical sets of values of Stephenson[63], Turner and Nicholls[64] and Bates[62]. All these provide a good check between theory and exper iment and also show that the new procedures adopted in carying out the distortion, show a definite tendency towards improvement of results over analytical methods, using harmonic oscillator.

(viii) *Bates' (Numerical Integration) Method.*

Bates[62] has very recently given an analytical solution to the radial part of the wave equation for a diatomic molecule by using directly the experimentally justified Morse expression. But he has used it to compute the transition probabilities by the method of numerical integration of the overlap integral.

Starting from the wave-equation for the nuclear motion in the radial part, and introducing the Morse function for potential energy in it, Bates obtains simplified form of the radial wave function by adopting the Laguerre polynomials. He arrives at the following general form giving

$$R_v(r) = r^{-1}.S_v(r)$$

or

$$S_v(r) = R_v(r).r \qquad \dots \quad (10)$$

where the series of values of $S_v(r)$ are given by

$$S_o(r) = A_o \exp\left[\frac{-\{\delta_e(1-x_e)+e^{-\delta_e}\}}{2x_e}\right]$$

$$S_1(r) = A_1[S_0(r)/A_0][1-(1-2x_e)e^{\delta_e}] \qquad \dots \quad (11)$$

Here A_v is the normalising factor for various values of v,

$$\delta_e = a(r-r_e) \text{ and } x_e = ah/4\pi(2\mu D)^{\frac{1}{2}}.$$

These functions can be evaluated for bands in any electronic transition for which the constant a, x_e, r_e are known. With these the wave function curves are drawn for various v' and v'' values. From these curves, the overlap integral $\int R_v'(r).R_v''(r)dr$ is then computed numerically taking proper account of the normalising factors, while obtaining the final measure of transition probability.

Bates himself applied the method to N_2(IP and IIP) and N_2^+ systems to derive the transition probabilities.

In the case of N_2 (IIP) system, he has calculated the transition probabilities for three upper levels $v'=0, 1, 2$ and four lower levels $v''=0, 1, 2, 3$. He compared these results with the earlier experimental data of Tawde[15] and others under four different experimental conditions. Taking the mean of these transition probabilities, he has found his computed results to give a fair agreement with them. Examining closely the variation of experimental transition probabilities of Tawde among the various sources of excitation viz. positive column of a discharge in air, discharge in nitrogen in presence of argon, spark in air and h.f. electrodeless discharge, some times wide departure is noticed from one source to another beyond limits of experimental error, especially for the positive column in discharge through air. In view of these divergent results, one has to see whether the conditions of excitation have something to do with the transition probabilities. At the same time, can there be any justification in taking the mean of such divergent results for comparison with theory ? These points have not been considered so far in such studies.

Langstroth[45] had earlier emphasised the need of obtaining integrated intensity values. These values were available from the work of Tawde and Patankar [13]. If Bates had used these values instead of Tawde's earlier peak intensities, his conclusion would perhaps have been different. In fact Korgaonkar, Desai and Laud[65] in our laboratory have later studied Bates' theoretical calculations in relation to the results of Tawde and Patankar and found decidedly a better support for the method of Bates.

Very lately Desai [66] working on the effects of argon on N_2(IIP) system, has tested Bates' theoretical values in relation to his own results. Using Bates' method he has extended the calculations by taking $v'=0$ to 4 and $v''=0$ to 5 so as to bring within the scope of comparison 16 bands more than the number taken by Bates. Need for such an extension was obvious in view of the large number of observable bands of the system, extending upto $v'=4$ and $v''=9$ or 10 and Bates used only a small fraction of this number. To this extent the theoretical data of Desai is most comprehensive, yet available on this system. (Vide Fig. 1(b) for eigenfunction curves.)

Desai has shown that his results along with some of the earlier observations on the system agree between themselves and with theoretical computations (Bates method) to a fair degree.

The values of Bates' on N_2^+ compare well with the latest computations by Pillow with a more refined procedure of distortion of the wave functions; mention of this has been made in the previous section.

It is possible to summarise the position of the theories both analytical or numerical integration methods, involving various procedures by studying the band system that has been exhaustively treated under most of them. Nitrogen (IIP) system is one such system on which good amount of

experimental work is done under different conditions in addition to theoretical computations by several authors. This data is collected below in table 1.

TABLE 1.

TRANSITION PROBABILITIES : 2ND POSITIVE SYSTEM OF NITROGEN

Band v' v''	Experimental values				Theoretical values				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
0,1	0.40	0.43	0.41_6	0.39	0.48	0.49_4	0.53	0.48	0.46
0,1	0.36	0.32	0.36	0.36	0.32	0.33_9	0.27	0.38	0.38_6
0,2	0.17	0.15_7	0.14_7	0.19	0.14	0.14_2	0.12	0.12	0.12_8
0,3	0.05_8	0.07	0.05_8	0.05	0.04_5	0.04_7	0.05	0.10_8	0.02
1,0	0.49	0.44_7	0.49_9	0.42	0.39	0.41	0.43	0.32	0.32_9
1,1	0.02_6	0.02_9	0.02	0.03_9	0.03_8	0.04	0.04	0.03_5	0.02_7
1,2	0.16	0.16_7	0.14_4	0.15	0.22	0.23_1	0.21	0.34	0.32_9
1,3	0.20	0.20_6	0.16_2	0.20	0.19	0.19_4	0.12	0.23_7	0.24_5
2,0	0.29	0.22_6	0.27_6	0.24	0.12	0.12_4	0.21	0.15_5	0.21_9
2,1	0.33	0.49_8	0.39_4	0.34	0.37	0.38_9	0.39	0.25_4	0.30
2,2	0.03	0.03_7	0.02_3	0.04_4	0.00_9	0.00_9	0.01	0.02	0.04
2,3	0.05_9	0.06_6	0.06_4	0.07_7	0.09_4	0.09_0	0.10	0.22_6	0.25
2,4	0.14	0.17_2	0.11_7	0.13	..	0.15_5	0.08	0.34	0.32

(1) Tawde (Mean of 4 observations)
(2) Tawde and Patankar
(3) Desai (Mean of 3 observations)
(4) Korgaonkar
(5) Bates
(6) Desai (Bates' method)
(7) Nicholls (Gaydon & Pearse's method)
(8) Tawde and Patankar (Hutchisson's method)
(9) Tawde and Patankar (Langstroth-Hutchisson method).

Variations that are seen among the different sets of theoretical values will result from a number of simplifying assumptions as well as different values of molecular parameters. The more precise the values of these parameters, the more favourable is the ground for test of theories. For, it has been shown earlier that the values of theoretical transition probabilities are very sensitive to slight changes in such parameters. Proper comparison of theories would require calculations from the same molecular constants. In above sets of values, the constants of different authors are not the same. The more modern constants used are those by Bates[62] and by Desai[66]; others[43,56] are from Jevons[67]. Considering these the following broad features emerge.

Bates'[62] and Nicholls'[68], results agree fairly well among themselves and they also compare favourably with experiment except for 2 bands. Both authors carry out numerical integration based upon the same eigenfunctions by different ways. Bates using directly the experimentally justified Morse potential energy expression and normalised wavefunction in the integration and Nicholls[68], starting from the parabolic curve of harmonic oscillator distorts it to fit the Morse expression. In this way they take account of anharmonicity.

Derivations from Hutchisson's and Langstroth's theory cannot be much different as they start from the same expression of harmonic oscillator except for the factor of excitation probability used by Langstroth[56] which effects a slight improvement over the former in case of excitation by electron impacts. But generally these predictions seem to be relatively

further from reality as evident from their comparison with Tawde and Patankars'[43], experimental integrated intensity results. The latter experimental results, for all practical purposes, can be taken to be comparatively free from any major errors and uncertainties involved in photographic photometry and are expected to give a closer approach to true state of affairs.

As regards the other independent experimental observations, they give a departure; but one has to see whether it is significant considering the variety of conditions under which the bands have been produced. However, in this connection there is ample evidence to feel that theories and refinements in them may have to take into account the proper excitation mechanism, including the external perturbations causing a redistribution of transition probabilities as envisaged by Zener[57]. The right choice of potential energy expression in the wave function is also a factor in the correct prediction of the transition probabilities. Further the transition probabilities are subject to the validity of the assumption that oscillator eigenfunction is independent of J, the rotational quantum number which is only an approximation.

It is a tacit assumption in all the theories that the electronic moment integral is independent of r, the internuclear distance. According to Shuler, if there is any variation of it with r, one has to see whether it causes a marked influence on transition probabilities. This point has not yet been investigated in any detail except in a single instance of OH ($^2\Sigma-^2\pi$) where the variation of electric moment integral with r is a more important factor in the calculation of transition probabilities than the use of more exact wave functions. Thus Shuler concludes that until some additional information is available on this point, not much reliance can be placed on the results of calculations regardless of how well the mechanical anharmonicity can be taken into account.

If this contention of Shuler is proved to be correct, then the extension of applicability of Hutchisson's theories to asymmetric molecules as suggested by Dunham [65] becomes also doubtful.

All the methods involve very laborious calculations. But in point of exact reproducibility of theoretical results, those involving numerical integration and particularly the distortion process would obviously be at a disadvantage.

3. Molecular Spectral Theories and Temperature

From the theories outlined above a vibrational sum rule of intensities can be derived, which allows temperature determinations to be made by the observations on band spectra.

If the vibrational eigenfunctions are properly normalised it can be shown with the help of the elementary properties of systems of orthogonal functions that the sum of the squares of the overlap integrals summed over all values of the vibrational quantum numbers of the upper or of the lower state is equal to unity. Thus

$$\sum_{v'}\left[\int \psi_{v'}\,\psi_{v''}\,dr\right]^2 = \sum_{v''}\left[\int \psi_{v'}\,\psi_{v''}\,dr\right]^2 = 1 \quad \dots \quad (12)$$

This condition in conjunction with the intensity expression in emission or absorption gives the relation

$$\sum_{v''} \frac{I_{v'v''}}{\nu^4} \propto N_{v'} \quad \text{(in emission)} \qquad .. \quad (13)$$

$$\sum_{v'} \frac{I_{v'\,v''}}{\nu} \propto N_{v''} \quad \text{(in absorption)} \qquad .. \quad (14)$$

These derivations have been used by Jablonski[70] to formulate the vibrational sum rule for intensities of bands in a system.

If emission or absorption intensity is divided respectively by ν^4 and ν, we obtain a quantity called *band strength.* The sum rule then is that the total band strength of all bands with the same upper or lower state is proportional to the number of molecules in the upper or lower states respectively. This becomes valid only if the electronic transition moment remains constant for all vibrational transitions, which contribute to $\Sigma I/\nu^4$ or $\Sigma I/\nu$.

Assuming thermal equilibrium at temperature T, at which the populations Nv of the initial state is proportional to $\exp[E_v/kT]$ we may write

$$log_e \sum_{v''} I_{v'v''}/\nu^4 = K_1 + (-E_{v'}/kT) \quad \text{(in emission)} \qquad ... \quad (15)$$

and

$$log_e \sum_{v'} I_{v'a''}/\nu = K_2 + (-E_{v''}/kT) \quad \text{(in absorption)} \qquad ... \quad (16)$$

Thus the knowledge of intensities in progressions and the vibrational energy term value provide a graphical method, giving a straight line for the estimation of temperature of the gas, emitting or absorbing the band system. Obviously, the intensities here, need to be only the relative intensities.

In emission this method will yield reliable results only if the excitation of the band system is purely thermal. But even for non-thermal excitation, often a straight line results from the above relation, and it becomes possible to obtain a value of temperature, which is then assigned as *effective vibrational temperature.* This and similar terms used for designating temperatures have not, in general, been properly understood and have, in many cases, led to a good deal of confusion in the study of temperatures of gaseous assemblies in a discharge or for that matter, the temperature of the discharge.

In a special investigational programme undertaken on behalf of the British Electrical and Allied Industries Research Association to determine to what extent thermal equilibrium exists in an arc discharge, Edels[71] has given an excellent critical resume of the work on this aspect. Achievement of this aim is possible through the knowledge and determination of what usually are termed the (1) electron, (2) excitation, (3) molecular band and (4) gas temperatures.

Within an electrical discharge, a number of different types of assemblies exist, viz. molecules, atoms, excited atoms and molecules, electrons, and ions. Each of these will have its component temperature comparative to the other characterised by a distribution, generally the Maxwell-Boltzmann (M.B.) distribution. The relative temperature conditions expected in these assemblies are that (1) electron temperatures will be generally much higher, irres-

pective of the pressure, than the other component temperatures, (2) they are also higher at the electrodes than in the discharge column (there may be deviation from M.B. distribution in the electrode region), (3) in the discharge column at high pressure no great differences exist in atomic, molecular and ionic temperatures, some times even the temperatures of electrons and (4) in regions of dissociation close to discharge boundary, differences between molecular and atomic temperatures may exist and this region may also depart from M.B. distribution.

Different experimental methods have to be devised to obtain the knowledge of all the different component temperatures and these component temperatures have further to be distinguished from the temperature of the whole gas within discharge boundaries i.e. discharge gas. This latter temperature we may term as *gas temperature.*

As we are concerned here only with the subject of molecular temperature or temperatures determined from band spectral intensities and transition probabilities, we ought to know what is *molecular temperature* and the fine difference between it and *gas temperature* and leave the other temperatures viz. *excitation temperature*, and *electron temperature* out of consideration.

Under *molecular temperature* we shall again confine ourselves to the derivation of temperatures from electronic band systems. In these there may be distribution of energy among rotational states at a certain temperature and similarly among vibrational states.

In terms of transition probability R^2, the expression for emission case comes to the form

$$log_e\, I/v^4R^2 = C_1 + (-E_v'/kT) \qquad \dots \quad (17)$$

We have seen above from the concept of vibrational sum rule how the temperature corresponding to the latter viz. *vibrational temperature* is derived. Similar considerations apply to rotational states and yield *rotational temperature*, the form of expression for the case of emission being

$$log_e\, I/iv^4 = C_2 + (-E_r/kT) \qquad \dots \quad (18)$$

where i=intensity factor

Using the vibrational intensity data on nitrogen positive and negative systems, Rosseland and Steensholt[72] have applied Hutchisson's[41] theory I of transition probabilities to derive the temperature for thermal equilibrium to be of the order of 30[illegible]0°K. This is very different from much more reliable figure of 250° obtained by Vegard[85] for a single band from distribution in the lines of R branch. Thus it was concluded that the theory breaks down at low temperatures. This is expected because it is not until high temperatures are obtained that collisions are likely to affect the vibrational intensity distribution. Hence a thermal distribution of rotational levels will exist for temperatures above a very low value, whilst for vibrational states one should expect such a distribution only at quite high temperatures.

In electrical excitations like those in certain discharges in gases or in arcs, high temperatures usually exist and thus a possibility of obtaining vibrational intensity distribution defining a temperature is indicated. Conclusions from application of these considerations to some laboratory sources are given below.

Band Temperature Results: A number of temperature determinations of laboratory sources have been made by using vibrational or rotational

intensity data. Taking C_2(*S*wan) bands alone, the temperatures have been derived under different conditions and sources by Johnson and Tawde[3], Lochte-Holtgreven[73] and Horst and Krygsman[74]. They generally vary approximately between 5000° and 6000°K. Taking CN bands, the temperature derived from rotational intensities ranges roughly between 6000°K and 7000°K either along the axis or in the cross-sectional plane as derived by Brige[75], Ornstein and Brinkman[60], Ornstein, Brikman and Beunes[76], Lochte-Holtrgeven and Macker [77], Mason[78], Kruithop and Smit[79], Tawde[16], and Tawde and Trivedi[18].

Similarly on nitrogen band spectra, a large number of determinations are available by Hamada[80], Ornstein and Harringhuizen,[81] Thompson[82], van Wijk[83] Lindh[84], Vegard[85], Tawde[15], Korgaokar[86] and Desai[66]. They vary between 250° to 5000°K according as determinations are from rotational or vibrational intensities and with variation of excitation conditions.

In general, the nitrogen bands are characterised by anomalies in temperature, both in rotational and vibrational states.

A few other molecules from which temperatures are thus determined are He_2 by Johnson and Turner[87], CO by Kanuss and McCoy[88], H_2 by Ornstein and Kruithop[89], AlO by Tawde and Trivedi[18], Tawde and Hussain,[19] Coheur and Coheur[90] and Tawde[91], BeO by Johnson and Dunstan[14] and Tawde and Hussain [19] and AlH by Nagashima[92].

In the case of C_2(Swan) bands, temperature results are in fair agreement with different authors. They also show that a high temperature high pressure source emitting these bands gives thermal distributions for both the rotattional and vibrational states which is unlike N_2.

Temperatures so far reviewed concern the production of a given molecule in different sources. The problem of the excitations of different molecules in the same source and of the same molecule arising from the different parent material or substances fed in a given source, has also been tackled by a few workers and some interesting conclusions have been drawn. From CN and AlO bands excited and photographed simultaneously in an arc, Tawde and Trivedi[18] found vibrational temperatures differing by a wide margin. This led them to suggest that they are excited in different regions of the arc—CN (6200°K) in central axial portion and AlO (3450°K) in the surrounding cooler flame part. Similar type of observations for these bands from rotational states are available from the work of Ornstein and Brinkman[60] and of Ornstein and van Wijk[93]. Tawde and Trivedi[18] have noted that the ratio of temperature CN/AlO in all the three independent observations remains practically the same, in spite of temperatures being vibrational or rotational. Somewhat parallel data on C_2 and CH bands in ethylene and acetylene discharges gives ratio of temperatures C_2/CH from rotational states, which is also nearly constant. The presence of hot and progressively cooler zones in the arc is not unusual. In fact, temperature gradient in a cross-sectional plane has been postulated for arc by Tawde and Hussain[19] from their results on BeO and AlO bands. In such a stable discharge, the bands due to CN, AlO and BeO or other molecules excited in arcs, locate themselves in regions or zones appropriate to their *optimum temperature* which is sufficient for their formation and insufficient for their dissociation. Coheur and Coheur[90] also find from intensity distribution in rotational lines of AlO bands produced in explosion of thin aluminium wires, in spark

and in arc, with variety of compounds of Al including its alloys for the electrodes or as material fed into the arc, that the temperature obtained always reaches an optimum value which has to be ascribed to the molecule. Thus it is evident from these observations that the bands may not indicate the temperature of the source, but their own optimum temperature.

As regards the excitation of a given band system arising from two different materials fed into an arc, it has been noted that the AlO bands produced in carbon arc, once with Al (metal) and another time with Al_2O_3 (compound), in lower electrode, give two different temperatures, but within limits of optimum temperature. Similar temperature differences have been attained for BeO bands with Be(metallic) Be(oxide) substance by Tawde and Hussain[19]. These differences for the same band system may have to be accounted for in a different way. In all these experiments on band temperature determination where carbon arc has been used for exciting the band system, the temperatures found do not go far from those obtained by other independent methods, such as sound velocity and absorption measurements. These methods give a measure of the *gas temperatures.*

Thus for arcs at atmospheric pressure the results indicate that the *gas discharge temperature* is of the same order as that determined from band intensity data. Further, such temperatures more or less coincide with temperatures determined from Saha equation. This suggests that with this type of discharge i.e. arc, no great difference exists between the temperatures of the discharge components, indicating a fair degree of equlibrium between them.

For discharges or sources other than arcs emitting the molecular radicals, the molecular temperature has been found to be generally different from the other discharge components. Because of this difference such a temperature is distinguished as *effective temperature* from the *gas temperature* which the whole group in the discharge would have by virtue of equilibrium or steady state. From the relative concentration of molecular and atomic entities which are usually far greater than other components, it is expected, under steady conditions in most discharge sources, that no great difference will exist between temperatures of different molecules present in the discharge Hence *molecular band temperature* determination will not be very different from the temperature measurement of the whole gas mixture. We know, however, that *band temperature* is usually representative of the "vibrational or rotational energy distribution of one molecule" and that if the temperature so obtained is unduly influenced by dissociation or by other processes, it is safe not to assume molecular band temperature to be the same as gas temperature and this happens in most discharges where steady state and ideal gas condition are usually far from being realised in practice. Spark conditions in particular offer an extreme case of departure in this respect, because of the rapid pressure changes. That may be the reason why temperatures derived from transition probability measurement of bands in sparks have given abnormal results.

If any correlation could be established between the *effective* and *gas temperatures*, an interesting field of investigation would be opened up in astrophysics. In the following we shall examine the application of the theories of transition probabilities to some problems of cosmic sources.

4. Transition Probabilities and Cosmic Sources

Molecular bands being of common occurrence in many cosmic sources, both in absorption as well as in emission, the molecular theories of transition

probabilities and intensity distribution measurements are now being increasingly used to identify the molecular radicals, to understand their excitation mechanism and to estimate the effective temperatures in cosmic sources.

Because of the complexities of mathematical expressions and the consequent labour involved in computations, there is an increasing tendency to make use, in astrophysics, of the laboratory data of transition probabilities. Once it is shown that such data is generally in confirmity with theoretical expectations, this knowledge could help the solution of some problems in astrophysics. How far such theoretical expectations are realised in practice has been shown in the previous section of this address. We shall examine now some of the applications of the more recent theoretical concepts of transition probabilities to derive information about phenomena in cosmic sources.

Wurm[47] used Hutchisson's theory to estimate temperatures in certain N-type stars by observations on CN and C_2 bands. He also calculated on the same considerations, the temperatures of radiating gases in comets by using CN bands. Application of theoretical concepts of Hutchisson[41] was made by Rosseland and Steensholt[72] to the spectrum of polar aurorae by using negative and positive N_2 bands. With the knowledge of temperatures thus obtained they postulated certain mechanism about excitation in aurorae.

In more recent years such work is being pursued especially in Canada and U.S.A. McKellar and Buscombe[50] have determined the intensities in the individual bands of C_2(Swan) and CN(violet) system to determine the excitation (vibrational) temperatures for reversing layers in three R-type stars H. D. 76369, H.D. 156074 and H.D. 182040. Comparisons have been made with theoretical values derived from transition probabilities based on Hutchisson's method of harmonic oscillator and with experimental results of Johnson and Tawde[3] and of King [51] on C_2. Later these results have been studied in relation to derivations from theoretical transition probabilities computed by Tawde and Patel.[48,49].

Observations using CN bands give theoretical and experimental temperatures for these stars. The object of these experiments apart from the derivation of temperatures was apparently to see how far the use of experimental transition probabilities could be justified for deriving the Stellar temperatures. Large disparities were noticed between the experimental and theoretical sets. They clearly indicated the need of obtaining more trustworthy experimental data. However, McKellar and Buscombe[50] have taken the mean of the temperature values of each of these stars derived from photoelectric colour measurements made by Dr. and Mrs. Kron of the Lick Observatory. To avoid some of the uncertainties, they have shown a method of using any bands of a system that have equal measured intensities by which it is possible to eliminate the effect of non-linear variation of absorption intensity with a number of absorbing molecules. The mean of the measurements by experimental and theoretical transition probabilities is also taken and the two sets of observations are given side by side.

	H.D. 156074	H.D. 182040
Mean of Dr. Kron's observations.. (Kuiper's scale).	5100°K	5700°K
McKellar and Buscombe's derivations— (Mean of theo. values of M. & B. and exp. of King, Johnson and Tawde, & Ornstein and Brinkman).	4700° ± 400	6200° ± 500

McKellar and Buscombe, find the agreement satisfactory, considering several possible sources of error in the method involving band intensities.

In view of the fact that the theoretical transition probabilities depend upon the several assumptions and approximations and since Hutchisson's theory has been shown to be inadequate to meet the reality, work of the type indicated above needs to be repeated in the light of the other transition probability theories of more comprehensive character that have given more satisfactory results. Among these we have indicated the superiority of the analytical methods using anharmonic oscillator eigenfunction and the methods of numerical integration, involving the direct use of experimentally justified Morse expression, viz., the method of Bates [62] or the one involving distortion of the parabolic curve to suit the Morse or other experimentally justified potential energy curve, viz., the methods of Gaydon and Pearse[58] and of Pillow[59a].

These tests ought to be extended also to the other astrophysically important molecular systems of CN (violet), TiO, ZrO, VO etc. Work on some of these molecules is already in progress at Bombay. Data obtained by one of the workers in our laboratories shows that TiO and LaO molecules occurring in M-type stars yield from laboratory sources, the vibrational temperatures of about 2000° and 3000° K respectively, which are generally within the range assigned to these stars.

The experimental transition probabilities of N_2 (IIP) system obtained by Tawde[15] in different laboratory sources have been utilised lately by Bates[62] to visualise the processes occuring in the earth's upper atmospheric sources, i.e. mechanism of excitation of nitrogen. Since the later experimental observations using integrated intensities by Tawde and Patankar[43] confirm the distribution theoretically predicted by Bates, to a greater extent than the earlier results of Tawde and also since the recent experimental and theoretical data by Korgaonkar[86] and by Desai[66] are in close agreement with these results, they may be taken to lend further support to the mechanism suggested by Bates.[62].

It has been found that the vibrational intensity distribution in AlO bands in Mira Ceti is different from the one obtainable in the laboratory. It has been suggested from this that the bands are probably excited by fluorscence resulting from the underlying radiation.

The temperature of the upper atmosphere layers in which auroral or night sky emission takes place can, in principle, be determined from the gross intensities of N_2 bands, as it has not been possible to resolve the rotational structure. Vegard and Tonsberg's[94] value thus obtained is 230°K. Temperatures come to be nearly the same for the bottom as for the top of aurora as well as for the sun-lit aurorae. These values cannot be reconciled with those from ionospheric data.

In general, the vibrational intensity distributions studied in laboratory and astral sources and from the standpoint of theoretical transition probabilities shed light on a number of problems connected with cosmic sources.

A promising growth of the astrophysical aspects so far presented and discussed would be in the direction of estimation of absolute theoretical intensities which is the problem of absolute strengths of electronic transitions in molecules. Mulliken[95] thought that a systematic development of the theory of absolute intensities of electronic transition and its application to the existing new data, would be "a step towards quantitative determination

of molecular concentrations in celestial objects besides its value for the understanding of molecular structure and spectra". According to the theoretical treatment of Mulliken the oscillator strength 'f' is derived in the form

$$f = \frac{\mu h c^2 \nu_{n,m}}{\pi e^2} \cdot B_{m,n} \qquad \text{... (19)}$$

where

$$B_{mn} = \frac{8\pi^3}{3h^3 c} \cdot |R_e^{n,m}|^2 \qquad \text{... (20)}$$

represents the transition probability from electronic state m to state n in absorption.

Swings[96] has indicated the desirability of f-data or absolute theoretical intensities for systems of CN, CH, NH, OH, TiO and C_2 (both symmetric and isotopic) in late-type stars. In addition to total f-values, those for specific lines or specific bands, are also of interest in astrophysics. Apart from their importance in stars and comets they are of equal value in the study of interstellar absorption.

Significance of f-values becomes apparent by reference to certain phenomena in cometry radiations. These are said to be due to fluorescence excited by solar radiation, from the nature of rotational intensity distribution obtained in the CN, CH and C_2 bands. Effective temperatures derived from such distribution in CN (3883) band of comets by McKellar[97] and Dufay[98] vary between 200° K and 435°K for heliocentric distances, ranging from 1.4 to 0.5 in astronomical units (a.u.) For CH bands they are much lower, the temperature at a distance of 0.5 a.u. being only 200°K. In the case of C_2 the temperatures derived are of much higher order (about 3000°K) with-only slight dependence on distance.

Differences in temperature either with distance or with molecular kind are to be interpreted in terms of the excitation of the radicals through repeated process by the solar radiation. Of the three molecules, CN and CH have permanent dipole, while C_2 has not. As a result, pure rotational spectrum of CN and CH is "permitted" while that of C_2 is "forbidden". These considerations will cause the excited rotational states of CH and CN to become depopulated by emission of the far infra-red rotational spectrum. While this goes on, a sort of equilibrium is established between rotation-increasing and rotation-decreasing effects of solar radiation, leading to a fairly low rotational temperature whose value goes on changing with intensity of solar radiation (i.e. with distance of the Sun), with the absolute intensity i.e. f-value of absorption of the particular band system and with the absolute intensity of the rotation spectrum (determined by dipole moment). In C_2, the populations will go on accumulating in high rotational states, with practically no chance of downward trend, causing abnormally high rotational temperatures. Thus on the basis of f-values or absolute transition probabilities, it is possible to explain the temperature differences.

The interpretation of cometary forms is possible through the knowledge of f-values. The shape of head and tail of comets arises as a result of recoil of molecules, following the act of absorption of light quanta i.e. by the introduction of the effect of radiation pressure. The magnitude of the effect depends on the intensity of solar radiation and the f-value for the particular transition. As a result a motion away from the Sun is superimposed upon the motion away from the cometary nucleus, giving an

elongated form for the head. Interesting features of such forms from theoretical standpoint have been discussed by Wurm[99].

With the available f-values Layddane, Rogers and Roach[100] have calculated the relative abundances of OH, CN, NH, CH and C_2 in solar reversing layers.

Probably more applications of f-data are still to come in the medium of interstellar space for which our knowledge is still meagre. For instance, with the availability of more reliable f-values for CH and CH^+ molecular absorptions, it would be possible to obtain a trustworthy figure of electron concentration in the interstellar clouds. Theoretical estimation of f-value for N_2^+ hands has been done lately by Bates [62] in order to interpret the processes in the earth's upper atmospheric layers. The approximations made with different simplyfying assumptions have yielded the following values of $f(\lambda 3914)$ which are 0.025, 0.034 and 0.095. One of these values compares favourably with the experimental value of CN, a molecule isoelectronic with N_2^+ determined by White[101] as 0.026, with higher limit at 0.035. Shull[102] has computed the theoretical f-value for these bands (N_2^+) arriving at the result 0.12.

Laboratory methods of determining f-values have been described by Oldenberg and Rieke[103] and others. Here the experimentally determinable quantity $\int k_\nu . d\nu$ is the integrated absorption coefficient which connects the transition probability through the relation

$$\int k_\nu . d\nu = N_{\mathrm{m}} . B_{\mathrm{mn}} . h\nu_{\mathrm{nm}} \qquad \ldots \quad (21)$$

and hence with f-value as shown earlier.

The way in which the results of absolute intensities of electronic transition i.e. f-values have been used so far, indicates their promise in future for the quantitative discussion of the phenomena of formation, dissociation, ionisation and abundances of molecules in the cosmic sources. Though the difficulties are numerous, this field ought to be exploited both from the theoretical and experimental sides, not only for direct observations in cosmic sources, but also in the laboratory, by investigating the molecular radicals associated with cosmic sources.

5. Transition Probabilities and Combustion Phenomenon

In the following we shall discuss the bearing of the results of transition probabilities in the vibrational, rotational and electronic states, on the problems of combustion in some of the flames.

Temperature dependence of distribution in vibrational and rotational states has been taken advantage of to see whether the emission of light in flames is due to (1) chemiluminescence (2) thermal or (3) pseudo-thermal excitation. This information is possible to be used to discuss the combustion processes. The *effective temperatures* obtained spectroscopically on the basis of theories can be used in conjunction with *gas temperatures* measured by any of the standard methods,[104,104a] such as line reversal method *or infra-red brightness technique* to postulate the probable reactions for production and excitation of radicals in flames.

Vibrational: The *vibrational temperatures* derived from C_2 (Swan) bands in reaction zones of several oxy-coal gas and air-coal gas flames by

Tawde and Patel[17,105] have led the authors to conclude that the C_2 molecules are not in statistical equilibrium in the upper vibrational states at the temperature of the source. This is in confirmity with the earlier view available from non-spectroscopic evidence. However, such is not the case with outer envelope of the flame cone, where Lewis and Von Elbe[106] have indicated the existence of statistical equilibrium from the observations on the infra-red radiation of the off-streaming completely burnt gas.

We have carried out lately an exhaustive study† of ethyl-alcohol flames in Meker burner with eight air-fuel ratios ranging from 5.2 to 9.8. From the results of measurement of intensities and temperatures, both vibrational and translational, it becomes apparent that the production of C_2 may be a consequence of thermal effects. From the relative strengths of C_2 CH and OH spectra, it is concluded that the poduction of C_2 may not follow from the reaction $CH+CH=C_2+H_2+25$ K.cal, as proposed earlier by some workers. This observation is in confirmity with the view of Gaydon[104]. On the contrary, CH appears to be the product of C_2 indicative of the reaction

$$C_2^*+OH=CH^*+CO$$

as suggested by previous authors[107,108]. This is evident from the intensity-temperature behaviour of the radical in the flames relative to C_2. Its production may not be purely thermal too.

The OH and CHO radicals do not give the same intensity behaviour as either C_2 or CH. The results for OH in inner cone are in favour of chemiluminescence as one expects for it. CHO shows similar variation to OH and may be an intermediate product between CH and OH. From the observation of overall intensity of the CHO bands relative to other radicals with variation in air-fuel ratios, we are inclined to discard the suggestion of Hermann and Hornbeck[109] that it is not likely to be an independent system, but the overlapping of four different systems (1) Deslandres *d'* Azambuja system of C_2,(2) Schumman-Runge system of O_2, (3) OH, (0.1) band at $\lambda 3428$ and (4) CH (1,0) band at $\lambda 5628$. This is a very substantial conclusion in view of the fact that the very existence of these bands which are the subject of critical study in respect if its emitter at present, was thrown in doubt for the first time since their discovery and classification by Vaidya[110] into two groups. In fact Vaidya,[111] in a recent paper, has applied the isotope test to assign the emitter of these bands by substituting duterium and has found positive evidence for vibrational shift in the A bands.

The bands have very lately been observed in fluorescence in formaldehyde and a few of the stronger members of the system have been excited in a discharged in formaldehyde by Dyne[112]. This goes to support the original assignment of Vaidya[110]. From the evidence of experiments reported by Dyne and Style[113], Vaidya[111] has suggested the nature of vibrator to be HC=0.

The vibrational temperature of C_2(Swan) and the flame temperature reveal that there is lack of equipartition of energy between vibrational and translational degrees of freedom. Examination of such aspects by including also the rotational degress of freedom would be a fruitful study.

Rotational: Taking the intensity distribution in rotational states, for combustion study, we find from the temperature derivations of Gaydon and

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Wolfhard[114] on CH radicals in low pressure flames of oxy-acytelene, that probably no case for thermal excitation exists and that the radicals may be excited by collision with active species in the flame without there being true chemiluminescence. Confirmation of the hypothesis was obtained in a later investigation by the authors.[115]

Rotational intensity investigations by us in CH (4315,3900) bands in ethylene-air flames have given temperatures that cannot be reconciled with the hypothesis of thermal excitation of the bands. The other alternative, viz. excitation of chemiluminescence may explain the observed results as per reaction:

$$C_2^* + OH = CH^* + CO$$

suggested earlier in the case of ethyl-alcohol flames. Such a reaction also receives support from Durie[116] from considerations of predissociation.

Excitation temperatures are found to be far from the true gas or translational temperatures suggesting the lack of equipartition of energy between rotational and translational degrees of freedom. Taken along with conclusions on ethyl-alcohol flames, this means that there is no equilibrium between the three degrees of freedom. Support for the lack in equipartition of vibrational energy as obtained spectroscopically is available from supersonic dispersion. As regards the lack in equipartition of rotational energy, Lewis and Von Elbe[106] suggest that this may be possible too on specific heat considerations.

The absolute (f-values) and Combustion: The knowledge of radiative and collision lives of activated molecule is important from the standpoint of combustion process in asmuch as they have a part in controlling not only the intensity of various band spectra occuring in them, but also in deciding which of the reactions is dominant therein. Capacity of energy-rich molecule to retain its energy has a part in the propagation of a chain; the formation of collision complexes and their stability with a large amount of internal energy determines also the combustion processes.

Average radiative life τ of a molecule is simply the reciprocal of its transition probability A_{21} from state 2 to state 1 governed by the relation

$$A_{21} = \frac{p_1}{p_2} \times \nu^2 \times 0.67f \quad \ldots \quad (22)$$

where f is the *oscillator strength or absolute intensity* of the particular electronic transition in absorption. and p_1 & p_2 the a priori probabilities of the two states.

From the combustion viewpoint Oldenberg and Rieke[103,117] made calculations of radiative life-time of excited OH radicals from measurements of f-values of absorption lines in 3064A° band in discharge through H_2O and H_2O_2 under high dispersion. Using these f-values the estimate of radiative life of the radical has been obtained as 4×10^{-6} sec. The knowledge of the existence of free OH radicals and their concentration thus provided through OH bands and their absolute intensity (f-values) is helpful in the discussion of the steps of a given reaction causing chemiluminescence. For instance, the combustion of H_2 in hydrogen flame may be discribed by a composite formula

$$2H_2 + O_2 = 2H_2O(\text{gas}) \; +114.2 \text{ K cal.} \quad \ldots \quad (1)$$

Obviously the reaction cannot proceed as shown with the simple collision of two hydrogen molecules and one oxygen molecule, without OH being shown as a free entity at some stage. Bonhoeffer and Haber[107] had earlier proposed the following two intermediate steps for the reaction (1) above to be completed:

$$H+O_2+H_2=H_2O+OH+98.9K \text{ cal} \qquad \ldots \quad (2)$$

$$OH+H_2=H_2O+H+15.3K \text{ cal} \qquad \ldots \quad (3)$$

Here we have a chain mechanism initiated by H atom and maintained by OH radicals.

The OH radicals, immediately on being formed, are either already in an excited state or get excited to upper $^2\Sigma^+$ state of the ultraviolet OH bands and then deactivate by radiation to the ground state ($^2\pi$) of the transition. The excited or normal radicals then combine as per reaction (3) to form H_2O and H. The fact that OH bands have been observed in absorption and emission in oxy-hydrogen flames by Wolfhard[118] and by Kondratiev and Ziskin[119] and that they have not been detected in absorption in slow thermal reactions at 550°C., as shown by Oldenberg and others[120] supports the above reactions in which OH radicals have radiative life time, depending on (f-value) of the particular electronic transition. There is no doubt that the reactions given can be interpreted in terms of the heats of elementary reactions and the heats of dissociation of molecules. More recent work on reactions involving OH radicals is due to Oldenberg and Sommers[121] and Hinshelwood[122].

The above considerations can be applied to the other combustion processes and chemical reactions too, if quantitative test of the existence of free radicals and of their concentrations is applied through absolute intensities (f-values) of electronic transitions.

The occurrence of CN violet system much more easily than red CN bands in flames and other sources, in spite of the requirement of more energy is interpreted thus in terms of its short radiative life time ($\tau<10^{-8}$ sec) calculated by White [101,123] from the measure of f-value (taken as 0.1).

The very recent estimate of f-value for C_2 (Swan) transition given by Shull[102] as 0.13 should mean a shorter radiative life-time than CN and hence much more ready occurrence of the Swan bands, a phenomena often met with in many flame radiations. Though work on estimation of f-values for electronic transitions and consequently on the calculation of radiative lives in molecules is considerably stimulated as a result of the development of these special fields, we have relatively only meagre data on these quantities.

As yet, even with the available knowledge of f-values or radiative lives and other spectral observations of the nature discussed in this section, there is no finality on the kind or mode of excitation, whether thermal, pseudo-thermal or chemiluminecscent and the reactions suggested thereof for the various radicals C_2, CH, CHO, OH, etc. in the hydrocarbon flames. The possible ways by which the observed material could be interpreted in terms of combustion reactions have been critically examined by Gaydon and Wolfhard[124] in a recent paper on the subject.

I hope this brief survey will give you an idea of the present position of the theories of transition probabilities in molecular spectra and also show

how they are proving useful in probing the distant and nearer phenomena that are still obscure or hazy to us. Both the fields of applications touched here are replete with a number of fundamental physical problems that are to be related on the one hand, to a variety of cosmic objects and on the other, to technical fields of importance to society by future investigations on molecular spectra on the lines suggested above.

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40th INDIAN SCIENCE CONGRESS, LUCKNOW, 1953
SECTION OF CHEMISTRY

Presidential Address

Dr. U. P. Basu, D.Sc., P.R.S., F.N.I.

CHEMICAL SCIENCE AND INDUSTRIAL PRODUCTION

CONTENTS

Introduction

Chemists and Chemical Engineers have been major contributors to the ever-growing standard of living and to the operation of the complicated technical economy in which all of us are to live. It is now a recognised fact that our existence is more and more dependent upon the efficiency of the nation's technological skill. A statistical survey would show that it is the science of chemistry that is playing a greater rôle in major technology than anything else, and that the chemical process industries are gradually increasing. For this growth again, a more basic knowledge of chemical sciences is necessary. The basic science is to be developed in the citadels of universities; and the industries by applying that knowledge, would offer a fresh impetus to pure science. The establishment of newer type of scientific and technological laboratories, as well as, the introduction of new and fresh course in various applied sciences in post-graduate training of the universities tend to justify the above statement. One of the objects of the Indian Science Congress Association under whose auspices we have assembled here today, is to advance and promote the cause of science in India. It is, therefore, essential that for the growth of the Association, we must have men of science from industry. This year the Association has elected one from the industry to the Presidentship of the Chemistry Section. For this, I must express my

thankfulness to the authorities of the Science Congress Association on my behalf, as well as, on behalf of many of my colleagues who are working for the growth of chemical profession and industries in India. In this connection I would like to pay my homage to (late) Dr. H. K. Sen from whom I received my early training in chemical research (pure and applied), to the great savant (late) Sir P. C. Ràỳ, who inspired me to serve the country through industry, and to (late) Capt. N. N. Dutta from whom I learnt the art of science in industry.

Factors for the Development of Industries in India

There has been no lack of investigational work in science in this country but until recently it has been carried out in academic rather in industrial laboratories. The method of approach by which science can be utilised for the benefit of society, would necessitate a sort of co-operative research amongst scientists of academic organisations and those in industries. Some are of opinion that the workers in the public institutions are being paid by taxpayers and they should not co-operate with those whose main concern is to make profits for a limited group. But this point needs careful consideration, since the welfare of an industrial concern in a country is of vital interest to every citizen and its prosperity virtually increases the prosperity of a nation as a whole. If the industry be controlled by one authority, further improvement of the products is likely to be slackened down due to want of competitive research, and it would be difficult to exploit the newer knowledge of the scientists as is being advanced and revealed from time to time. A survey might give an idea of the benefit which the public has received through private enterprise and competition. In no other branch of the chemical industry is competition so great as in the field of fine chemical and pharmaceutical industry. Many advances in this industry have rendered the flourishing ones almost useless. For example, with the advent of sulfa therapy the anti-bacterial serum became practically obsolete; one may even think over the future of sulfa industry in view of the new antibiotics coming into the field. Of course, one may raise the question of the necessity of any such discussion in India as our industrial activity cannot be compared with that of many of the more advanced countries of the West. But a nation that would like to advance, must find out her shortcomings and take necessary steps for removing them. The first question that would arise, is what are the causes that have been detrimental to the progress of industrial activity in India. In making any survey it would be found that though there are enough raw materials in India, they have not been fully utilised within the country. Further, in industrial practice we need four classes of people namely, artisans, technicians, technologists and scientists. There are many artisans very thorough and expert in their line. "Some of the boys do work in a way which would take a life time of the workmen in the British Shipments to adopt"—was the opinion of some foreign experts going round the Vizag shipyard a few years ago. The efficiency and technical skill of the Indian workers and technicians would be found in various other fields[1] also. But when the industry demands qualified technologists and scientists, there is found some dearth of people in our country. Qualified scientists for various reasons, social and /or economical, do not prefer to join the industry. The reasons for non-development of large scale industries are many, but some of the more important ones are recorded:

(i) *Policy of the State*: Previously the State encouraged the development of industry from materials imported from abroad, or for materials

suitable for export to a foreign country. Any enterprise for building up an Indian industry on Indian work was obstructed by the sale of a similar imported product at a cheaper rate, or, by the non-supply of the machinery and the basic materials required for the industry. The Statutory Laws and Regulations were also detrimental to the industrial progress of the country.

(ii) *Lack of training and co-ordination*: The State had no clear-cut industrial policy and as a result industrial research with properly trained personnel was seldom conducted in any State, University or Public Institution. A few firms made an attempt but they were not working in collaboration. The scientific training also was such that the students could not make much use of the same in industry.

(iii) *Want of co-operation among the Industrialists*: The Indian Industrialists hardly worked in tune. One firm instead of helping another in its mission, was found to imitate its products and try to lure away its technical experts.

(iv) *Want of patriotism and love for the Nation*: In general it would be found that we were more interested in individual gain rather than the national gain. Recently some Indian firms have tried to build up relation with Foreign firms. Most of the latter bodies are merely branches of their parent firms whose resources are incomparable with those of Indian firms. Any foreign private investment is to be very carefully scrutinised.

(v) *Lack of enterprise among the Industrialists to spend money on research*: Research is considered to be the backbone of industry in every industrially developed country. But in India very few industrialists believed in research. The main reason was that in most cases they were often making profit by exporting crude products, or, by selling imported products. Naturally they were more in trade rather than in industry.

(vi) *Outlook of the scientists*: The scientific workers of the State, or, University also did not feel the necessity of co-operative research. Any research team is a carefully co-ordinated and integrated group of specialists each adhering pretty closely to his speciality but working together under efficient direction and administration. They must have a training in body and mind to move in a team.

(vii) *Want of confidence*: The people in all walks of life must have confidence in themselves and should believe that others are also working for the interest of the community and the nation. A feeling of brotherhood and patriotism is also essential for the industrial growth of any country. But distrust prevailed in all spheres.

Patent System and Industrial Development

There are countries like Sweden or Switzerland where the industry is far advanced inspite of the want of many essential raw materials. They have co-ordinated the work, have developed the art of chemical technology amongst their workers and have consequently made a rapid progress. In this connection a reference must also be made to the utilization of the patents in the advanced industrial countries for building up their national industries. The patent system in India is in existence for near about a century, but the Indian industrialists have made a very little use of it for developing industries. In order to investigate why patent system has not served its purpose in India, a Patent enquiry committee was appointed by the Union Government in

1948 who submitted their final report in 1950. The full report is still under careful consideration of the Union Government but as a result of an interim report on "Compulsory Working" of the patented invention in India the law was revised and has come into force from April, 1950. The amended law will prove very effective in developing industry in India, if Indian industrialists take advantage of the revised Act.

The value of the Patent System in promoting industry has been recognised throughout the world, but unfortunately Indian scientists and industrialists had not appreciated its value in the past. Almost all the countries of the World have their Patent System. Even Russia that does not believe in private enterprise or monopolies, has patent system of their own. As a result of prejudice against monopolies Holland abolished her Patent System in the year 1869 when she was also a manufacturing country like England, France and Belgium. After 40 years of experience without a Patent System, Holland found that export of manufactured articles dwindled and that she had been reduced to an agricultural country. This result could not be attributed to want of enterprise on the part of the Dutch as they are industrious people. Holland found to her cost that the change was due to want of Patent System, and accordingly, she re-introduced the Patent System in 1912. Since then, she has been able to regain past position and zealously maintaining her Patent System.

Another example of the effect of the Patent System in the development of industries is found in the case of Switzerland. Inspite of the fact that Switzerland was a comparatively industrial nation, having world wide reputation as a producer of watches and other manufacturers, she suffered from the American competition which was backed by technological improvements sustained by the American Patent System. So in 1888 Switzerland founded the Patent System, and since then, inspite of the handicap of lack of mineral resources like iron and coal in the country, she has become a leading industrial nation of the world. Her industry of machine tools and fine chemicals is unrivalled at present. The effective use she has made of the Patent System in getting this result, will be evident from the number of of patents (pre-war figures) as shown in Table I.

TABLE I

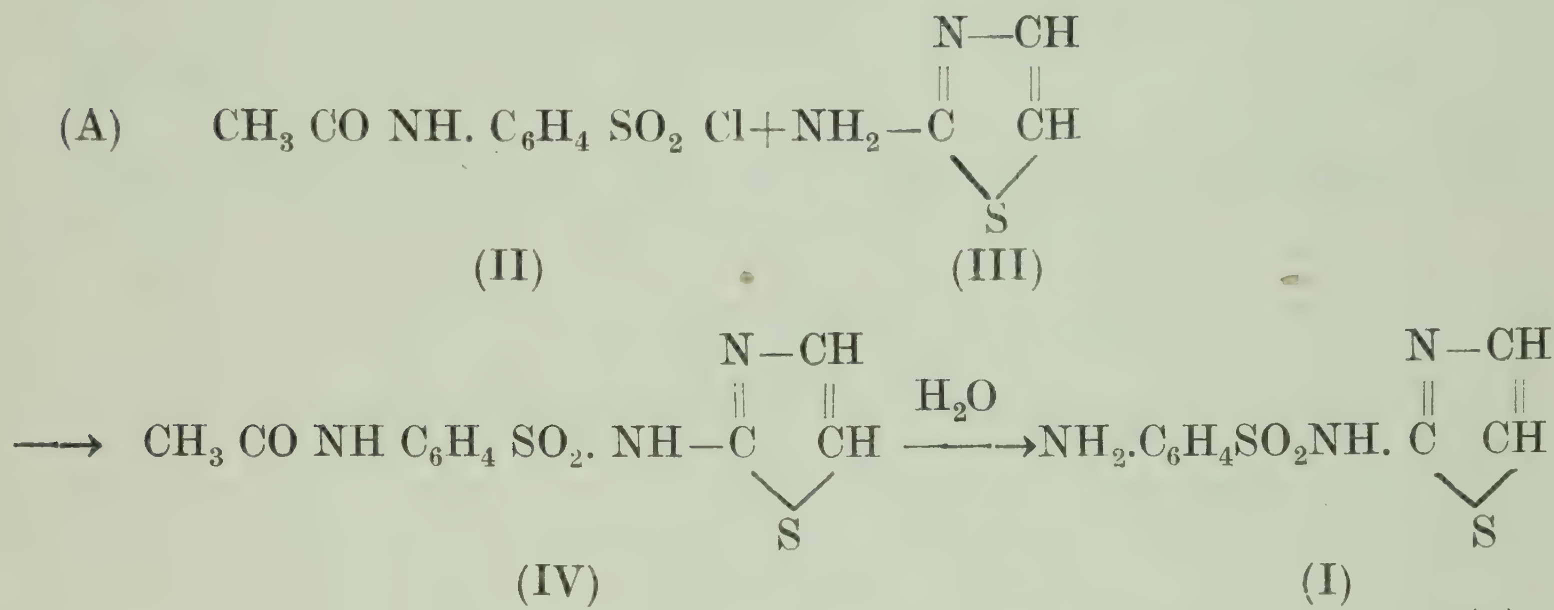
Name of the Country.	No. of patents granted per million population
Switzerland	1016
Belgium	892
Great Britain	493
U. S. A.	394
India	2

From the Table I it is evident that though Switzerland introduced the Patent System much later than the countries like U.S.A. and Great Britain, she has the highest number of Patents granted per capita of population and has a prominent place in the industrial map of the world by using the Patent System.

Some of the advantages of the Patent System be narrated for indicating its importance:

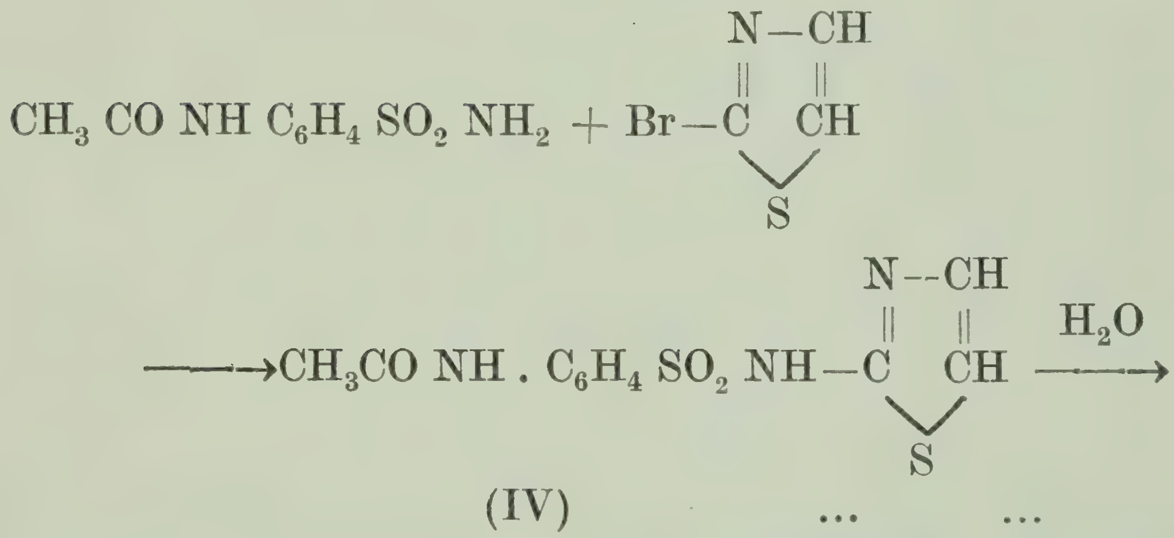
(i) Patents create a situation whereby persons working in same field get impetus for making inventions. The rapid progress made in the field of sulfa durgs, or, antibiotics, has been mainly due to the existence of Patent System. Rival firms became interested to find out alternative methods for producing those drugs so that they could put the same in the market without infringing each other's rights and also might obtain the products in an improved form and at a cheaper rate. As a result we find that there are now about 6 to 7 dozen patents on each of the above subjects. If this point be deeply considered, it would be found what tremendous developments in scientific methods and ideas are to be revealed for opening out a new channel in the production of the same material by a different route. Thus for the preparation of the drug, p-amino benzene sulphonamidothiazole (I) the following alternative processes have been discovered and patented:

(A)



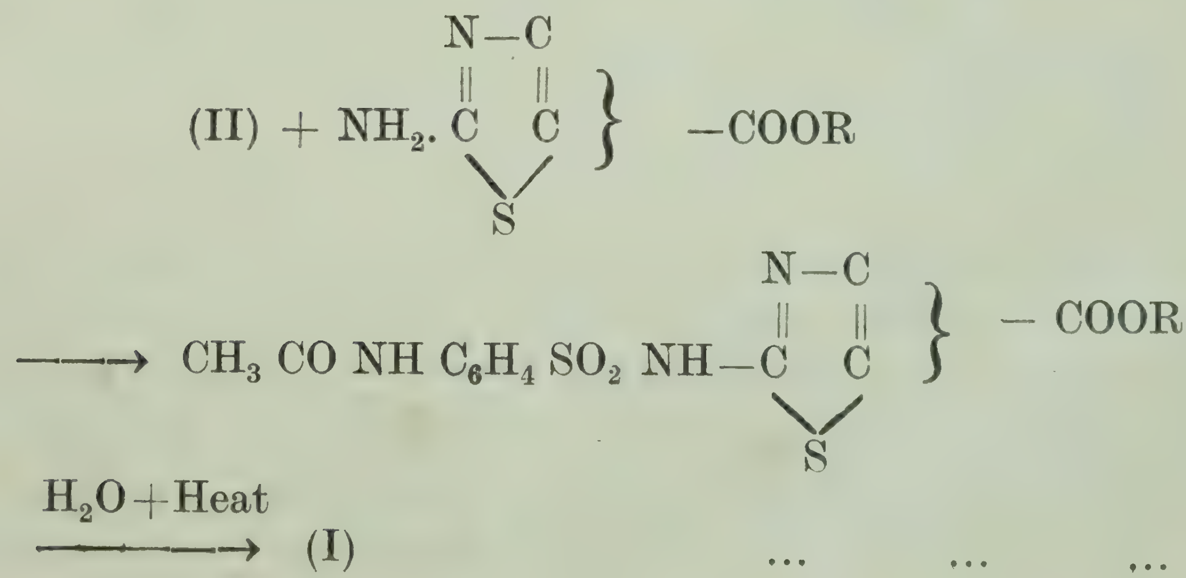
... ... (2)

(B)

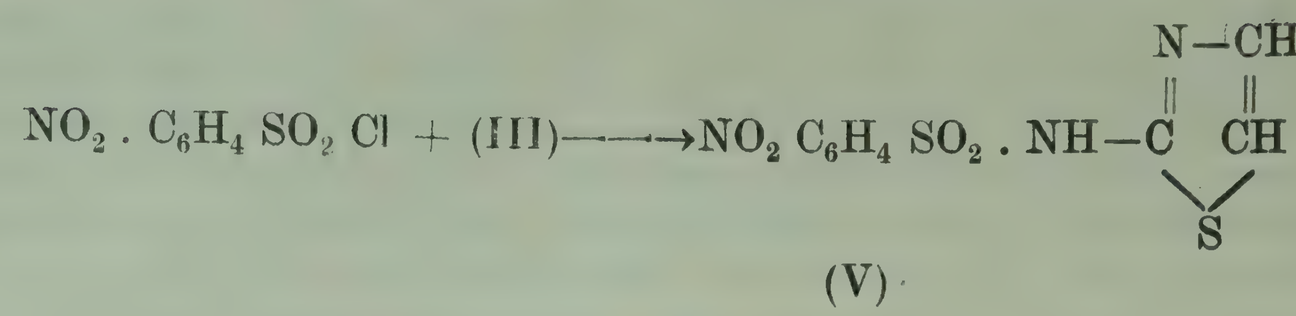


... ... (3)

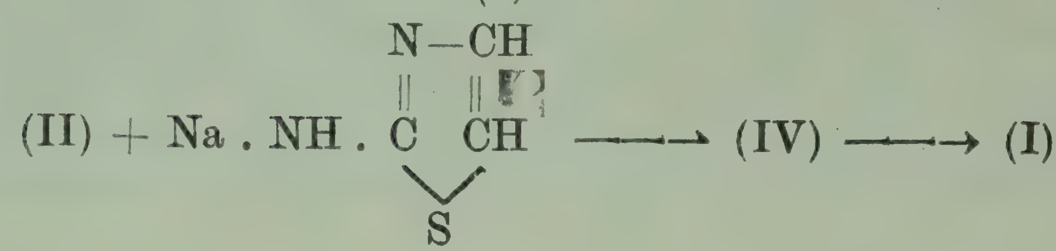
(C)



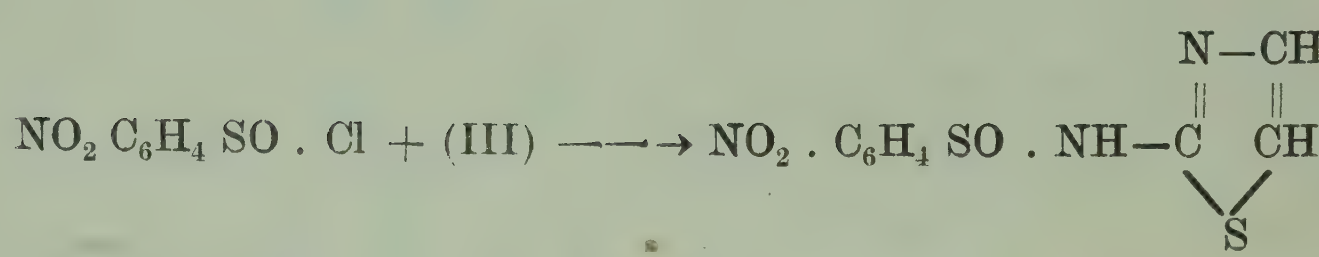
... ... (4)

(D) 

$\xrightarrow{H_2}$ (I) ... ... (5)

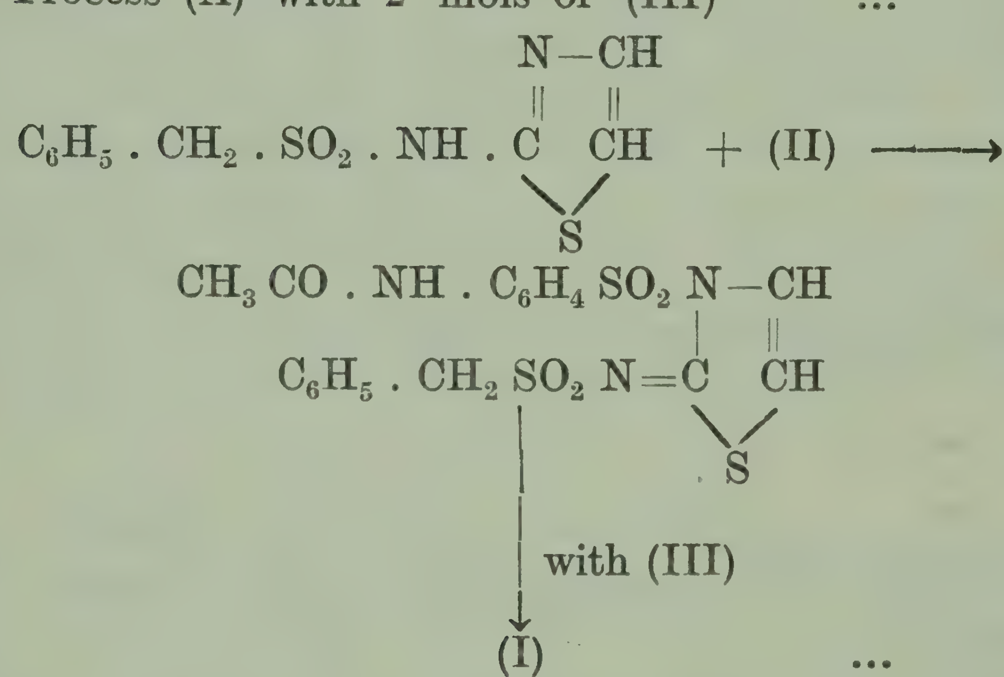
(E) 

... ... (6)

(F) 

$\xrightarrow{O_2}$ (V) $\xrightarrow{H_2}$ (I) ... ... (7)

(G) Process (A) with 2 mols of (III) ... ... (8)

(H) 

... ... (9)

(I) $CH_3\,CO\,NH\,.\,C_6H_4SO_2NH_2 + RS.CN \longrightarrow CH_3\,CO\,NH\,C_6H_4SO_2NH.CN$

$\longrightarrow$ Na Salt $\xrightarrow{(NH_4)_2\,S}$ $CH_3\,CO\,NH\,.\,C_6H_4\,.\,SO_2\,NH\,.\,C(:NH)\,.\,SH.$

$\xrightarrow{Cl\,CH_2\,CH\,(OR)_2}$ (IV) $\longrightarrow$ (I)

... ... (10)

(ii) An invention dedicated to the public without protection against competition is actually wasted and lost from the standpoint of industry. This may amount to a loss of national wealth too. The production of food-stuffs or substance possessing antirachitic properties by irradiation, was originally the work of British Scientists. These British Scientists most probably thought that public interest would be best served by dedicating the fruit of this research to the public and accordingly they did not take out

a patent. But soon afterwards a patent was granted to Steenbock of Wisconsin University, U.S.A. for a modified process of irridiation of foodstuffs. The University not only used the patent to demand royalties in England for using the process but also tried to control the manufacture of Vitamin D, which was subsequently found to be an outcome of irradiation. Similarly, in early days the British dyestuff industry suffered very much as British scientists were not interested in patenting their inventions whereas Germans had monopolised the field by covering their inventions by patents from the very outset. This situation was saved by a drastic change in the British Patent Laws so as to enable the British industrialists to take out patents for alternative methods for preparing the dyestuff patented by Germans in England.

(iii) Inventions need development before they could be adopted for industrial purpose. This involved a large investment of capital and labour which will not be forthcoming unless the enterprise is free from the risk of competition. Protection enjoyed under the Patent would enable the patentee to disclose his invention to industrialists without any risk so as to raise capital for working the invention on commercial sacle . Industrialists would like to invest capital for the development and working of the invention under Patent protection as there will be less fear of competition.

In order to cope with the situation industrialists would, therefore, have to expand their scientific activities and spend more money for research and development. Here is a remark from the Presidential speech to the British Association of Science by Dr. Sir Henry Tizzard which may be quoted: "Industrial prosperity will depend more and more on the continuous application of a science to industrial practice. Unless we can raise our standard of technology, unless there are many more men in executive positions in industry whose practical experience has been preceded by a scientific education, we shall inevitably fail to keep our place among the great manufacturing nations". This remark is of considerable significance in India. We have already several national laboratories, we have now a technical school on the model of the Massachusetts Institute of Technology. It is expected that we would in near future, get a band of trained men in various fields for our industries. These scientists and technologists must also be trained in body and mind, as in practical fields they must know each other and will have to work in co-operation. This is more so in modern drug industry as the discovery of a newer drug and its large scale production for the use of the common man, demand co-operative research and co-ordinated work from different and diverse types of scientists and technologists. The evaluation of a new antimalarial, the isolation of an antibiotic, or, the synthesis of a potent keto-steroid shows how the whole science of chemistry with all its ramifications is in need of being pressed into service for making any advancement in modern therapeutics. Malaria, which is one of the world's greatest disease problems, causes 3,000,000 deaths a year, putting more than 300,000,000 people into sick beds and destroying vast productivity. The antimalarial that has been in use for a very long time is quinine. Its drawbacks as well as its non-availability during the first World War led the German scientists to search for active synthetic compounds. Plasmoquin (Pamaqu n) is practically the first synthetic anti-malarial but its toxicity induced th inventors (the Germans) to carry on the investigation further. This atte mpt helped in the production of "Atebrin" which was in large demand dueriing the World War II. But "Atebrin" causes pigmentation and needs daily administration for the suppression of malarial attack. A more highly effective non-toxic suppressive drug was needed, and extensive investigations

carried out in Germany, England and in U.S.A. resulted in the production of drugs like "Chloroquine", "Paludrine" and some others; but all are from the factories of countries abroad.

Difficulties in Production

Let us consider the problem that may arise in the production of a material, say, for an antimalarial drug in quantity. If we take a known product like Atebrin, then the requirement for one course of treatment for 100 million sufferers in India would roughly be 3,33,000 lbs. If some of our people are treated with quinine that is being produced in the country (approximately 90,000 lbs.), even then the requirement for Atebrin (mepacrine) would reach a figure of 3,10,000 lbs. The essential chemicals for its manufacture are toluene, benzene, acetone, acetic acid, nitric acid, hydrobromic acid, alkalies, fusel oil. chloroform, phosphorous oxychloride, thionyl chloride, chlorine, metallic sodium and diethylamino ethanol (or simple diethylamine). The "know-how" is and was known to some scientific workers of the country. But, for its manufacture the chemcial industries would have to supply considerable amount of materials as mentioned above. Some of them like toluene, benzene, acetone, fusel oil etc., were being produced in the country but their supply was restricted for strategic reasons during the War periods. Metallic sodium, phosphorous oxychloride, thionyl chloride, and diethylamine were not and are still not available within the country. An indigenous production, therefore, demands the availability of the above materials. Some may, however, be imported from abroad. America too, before World War I, or immediately afterwards, produced many syntheticals from intermediates imported from Germany. But for national interest a start was made for production within the county; developments followed and the country gradually became self-sufficient in its essential requirements. A point is to be mentioned that production of organic syntheticals is also largely dependent on the ready supply of common inorganic materials like sulphuric, nitric and hydrochloric acid, and that again of different strength and purity. The question, naturally arises whether we were self sufficient in that respect and whether we are still in a position to meet our requirements. The shortness of sulphur is causing an unbearing headache to those who are interested in the manufacture of sulphuric acid in India till now. Similar question may be raised on the availability of other common materials like caustic soda and soda ash from indigenous sources. Apart from the want of certain intermediates, solvents, or gaseous products, the manufacture of drugs, pharmaceuticals and fine chemicals involves a series of operations that need various equipments and appliances. Full scale development of the industry would demand the availability of all these materials within the country. Successful production of chemical plants and machineries would again necessitate the development of special steel and non-ferrous metallurgical industries. Availability of the different types of metal sheets, pipes, rods and plates, knowledge of designing and production of certain electrical and mechanical equipments are at the root of the development of chemical engineering plants. Again, in producing chemical products in quantities the chemical industry will have to consume considerable amount of cheap electric power for process working. Proper performance demands accurate and reliable application of electric power for primemovers, generators, switch-gear agitators, grinding machine, pumps, blowers, compressors, pulverizers, crushers, heaters, furnaces, and many other chemical plants in installations. A thorough training and application of the knowledge

of design as well as trained service men to keep everything running, are absolutely essential for the economic progress of industries. It may, however, be now said that a good start has been made in all the above directions, and the move would soon acquire a momentum provided we remain patriotic. There might be some pitfalls in our training centres, or, in the running of our industries. But it may be expected that the All India Council of Technical Education would look into the former, and the newly formed Central Advisory Council under the Industries Act 1949, would provide a vital link between the State and the Industry for the purpose of promoting sound industrial development.

Inspite of many shortcomings, the Indian infant industries in certain cases made attempts to produce several products for ameliorating the suffering conditions of the people. Unfortunately, many such attempts have been frustrated partly due to absence of the timely response from the State authorities, partly due to the shortcomings in many of the Statutory Acts and Laws, and partly due to want of patronage from the public. Attempts are now being made to rectify these but it is to be noted that the pre-requisite for taking the fullest advantage and benefits of science through industries is the creation of a co-operative spirit amongst the State, the University and the Industry. The scientists of the divergent units of the country should adhere to their own path of axiom and try to reveal more and more the newer knowledge of science and technology. The industry should again understand that for the University and the State that are to remain in constant touch with the public, nothing is more harmful than secrecy. The Government should also feel that planning made from the centre cannot be perfect as the decisions made by a Central Authority can be in broad terms only. The science has come to a stage where any new work would need help from workers in the different fields. This would be more clarified, if we consider the problem of evolution of a drug. Let us take again the case of a new antimalarial.

Work for Evolution of a Product (Antimalarial)

We possess several suppressive drugs of great antimalarial effect. The clinical manifestations of malaria can now be suppressed by weekly drug administration. They are effective in controlling the *blood-stream infection*, but they do not *sterilize* it. The antimalarials in common use, are unable to act on the "sporozoites" (form of malaria parasite injected by the mosquito at the time of biting). We are not very definite about the fate of these malarial parasites. Fairely[11] made a notable observation that the sporozoites introduced by infected anopheline mosquitoes could be detected in the peripheral blood only for 7 to 30 minutes after the bites, that, thereafter, a period of 6 days in the case *P. falciparum* and eight days in the case of *P. vivax* a non-infectivity followed. The malaria parasites retreated into some internal organs. After this incubation period they reappear in the red blood corpuscles. If these sporozoites could be killed at this early stage of their life cycle (i.e., within the first 6-8 days) inside the solid tissues, it is obvious that actual prevention of malaria would immediately be achieved. A chemotherapeutic research would, thus, demand a complete knowledge of the biology of the malarial parasites, their action on the drug-host system, the various enzymatic reactions involved, syntheses of suitable chemical agents which would attack the sporozoite development stage, or destroy the exo-erythrocytic forms, their production and subsequent uses as prophylactics.

Plasmoquin (pamaquin), the synthetic antimalarial, is prophylactic in both vivax and falciparum infections. Its curative properties in vivax malaria are evident from reduction in the relpapse rate of the disease after treatment with this drug in combination with quinine. In very small doses it abolishes the sexual forms of the parasite which transmit the disease to the mosquito when it sucks blood from infected man. But its great drawback is its toxicity particularly when administered to darker skinned races and it is often so great that it precludes prolonged administration in endemic areas. Various types of compounds have been synthesised but none possesses those characteristics by which they might stop relapses and thereby, cure vivax malarial infection.

The only known drug having curative properties in this disease is the plasmochin or its other homologues—all derivatives of 8-amino-quinolines (*cf.*, Fairley[12]). The question arises wherein lines the property of killing the tissue stage of *P. vivax* in 8-aminoquinolines and what are the causes for their toxicities? Extensive investigations have been directed towards the synthesis of some more effective product by altering the side alkyl amino chain retaining the basic character of 8-amino-quinoline unchanged in pamaquin. Lengthening, or, branching the side chain, alteration in the state of terminal nitrogen, or, size of the terminal alkyl group influences to some extent the toxicity of the compound (Basu[13]). Pentaquin, 8-(5′-isopropylamino amylamino)-6-methoxy quinoline (Alving[14]), has greater curative activity and lower toxicity than pamaquin. The iso-pentaquine, 8-(4′-isopropylamino -1′-methyl butyl amino) -6-methoxy quinoline, has the only advantage over pentaquin in that the margin between the effective therapeutic dose and the maximum tolerated dose is greater. The primaquin is still less toxic (Edgcomb, *et al.*[15]). Linking with a newer type of side chain, like phenyl biguanide (*cf.*, Basu *et al.*[16]) the antimalarial activity is retained and it is of interest to note that if the above biguanide linking is changed by a simple guanidine, the antimalarial activity is practically annulled. Simple guanidines, however, exert pronounced activity [17] against sporozoite-induced infection of *P. gallinaceum* in chick. Because the malaria organisms parasitize the red cells it is most natural to expect that the efficacy of an antimalarial would depend to a considerable extent on the concentration one may attain in the red cells. The observations of Teggart *et al.*[18] show that such concentration of different drugs varies considerably. Mepacrine, Chloroquin, or, Proguanil is soluble in the red cells in the same proportion as in the plasma; whereas concentration of quinine with the red cells is only one-eighth of that in the plasma. This explains at least in part why the high doses of quinine are necessary in the treatment of malaria. The solubility of a drug would depend on rate of absorption of the drug from the alimentary canal, the competition between the red cells and other body constituents for the drug, and the rate at which it be degraded in, or, excreted out of the system. The behaviour of mepacrine[19], chloroquine[20], and Paludrine[21] has been considerably studied. They are rapidly absorbed and peak concentrations are attained within a short period. Quinine and 8-aminoquinoline differ from them in the speed with which they disappear from the body. These drugs undergo degradation and it is still a problem whether their activity as well as their toxicity is due to such alteration. Archibald and Weisiger[22] are of opinion that the toxicity of plasmoquin is due to the formation of a complex with aldehyde or ketonic bodies in the system. It is of interest to note that the plasma concentration levels of 8-aminoquinolines might be considerably increased by concurrent administration of mepacrine and paludrine but not of quinine (*cf.*, Zubrod, Kennedy, and Shannon[23] and

Jones *et al.*[24]). It is, however, the quinine that enhances the curative effect of 8-aminoquinolines. A similar potentiation of the activity of plasmoquin has been noticed by Walker[25] in concurrent administration of a naphthoquinone derivative, 2-hydroxy-3-(2′-methyl octyl)-1:4-naphthoquinone. To account for all these phenomena, one will have to study the fate of these drugs when administered into patients suffering from malaria. This would, simultaneously lead one to study the biological characteristics of the malarial parasites, and the whole drug-host parasite relationship. Existing knowledge is scanty and a thorough investigation on the above problem will be of great interest. The Council of Scientific and Industrial Research, Government of India, has sponsored a scheme on this complicated nature of work. This is being followed with enthusiasm in the Bengal Immunity Research Institute and is gradually getting a momentum.

Antimalarials and Malarial Parasites

Inspite of the investigations so far carried out on the malarial parasites, inspite of the availability of so many schizonticidal drugs, and inspite of our recent knowledge of the tissue forms of *P-vivax* responsible for the maintenance of the malarial infection, we have no weapon to destroy the *late exo-erythrocytic* forms of the parasites that cause relapses. What we need today, is a basic information on the host-parasite relationship in the presence of a drug. Until recently, we were not even aware of the fate of the parasites after their entry into the peripheral blood. Shortt[26] in 1950 demonstrated the presence of pre-erythrocytic forms in human malaria. He allowed 2010 mosquitoes infected with *P. vivax* to bite a human volunteer on two successive days. The volunteer was operated upon seven days later and a piece of liver removed. On examination this was found to contain schizonts of *P. vivax*. These schizonts measured upto 42μ in diameter and 7 days old contained over 1,000 nuclei. It proved conclusively the existence in vivax malaria of pre-erythrocytic forms in the parenchymal cells of the liver. They would remain unaffected by the natural immune bodies, humoral or cellular or both. The problem would be to destroy the parasites at this site or even before they enter the parenchymal cells of the liver. For this we must know how the parasite maintains its metabolism. The common belief is that the respiratory mechanism in malarial parasites follows almost the general scheme of biological oxidations. Christopher and Fulton[27], showed that antimalarial drugs like quinine and atebrin inhibit the oxygen consumption of malarial parasites. Silverman *et al.*[28] noted that quinine at a concentration as low as 6×10^{-6} *M* inhibits the respiration of suspensions of parasitized erythrocytes. The *in vitro* action of mepacrin at low concentrations on the metabolism of *Plasmodium gallinaceum* appears to be similar to that of quinine in causing an inhibition of oxygen uptake which is associated with an increased formation of lactic acid,—a normal glucose utilization. According to Speak and Evans[29], the mode of action of quinine and atebrin on malarial parasite is probably due to the inhibition of some oxido-reduction enzymes somewhere in the oxidative breakdown of pyruvic acid to carbon-dioxide and water. Hass[30] has found that the antimalarial drugs like quinine and atebrin have got an inhibiting action on cytochrome reductase and cytochrome oxidase, and only mepacrin, not quinine can inhibit glucose-6-phosphate dehydrogenase. Haas has further observed that quinine is much less effective than atebrin as respiratory inhibitor. Our observations also establish that mepacrin (atebrin) has got a greater inhibiting action on

succinic dehydrogenase prepared from *Plasmodium gallinaceum* than quinine. The inhibition of succinic dehydrogenase by quinine *in vitro* apears to be insignificant in comparison with its antimalarial effect on the malarial parasites. Moulder[31], in studying the inhibition of pyruvate oxidation on malarial parasites, noted that the inhibition in case of quinine was much greater when the antimalarial was allowed to act *in vivo*. This naturally points to some change in the molecule of quinine and suggests that a metabolic product of quinine is more active than the alkaloid itself. Similarly in case of the drug paludrine, it has been recently claimed (*cf.*, Carrington *et al.*[32]) that a triazine derivative formed in the system is the active substance that might be responsible for the characteristic antimalarial property of paludrine. Inhibition of the function of an enzyme system in *in-vitro* experiments, is not being found to be proportional to the concentration of a drug (*cf.*, Silverman *et al.*[33]). This has also been noticed in our Institute during the study of the action of quinine on succinic dehydrogenase.

The interesting observation that has been recently recorded during the biological studies on malarial parasites by one of our colleagues, is that the inhibiting action of quinine on succinic dehydrogenase can almost be completely reversed by an equimolar concentration of cysteine. This reversal suggests that the action of quinine is due to suppression of the activity of the sulphydryl group of the enzyme. The latter might be either for the oxidation of the -SH group, or, for the formation of some additive complex. We cannot say definitely by which mechanism quinine inhibits the enzyme—succinic dehydrogenase. A survey on the literature shows that antimalarial drugs possess a general tendency of inhibiting the SH-enzymes, e.g., glucose -6-phosphate dehydrogenase by atebrin (*cf.*, Haas[30]), d-amino acid oxidase by atebrin by Wright and Sabine[35], phosphatase of co-carboxylase and yeast carboxylase by most of the common antimalarial drugs by Silverman[36], hexokinase and phosphoglyceraldehyde dehydrogenase by quinine and atebrin (*cf.*, Marshall[37]) and succinic dehydrogenase by several drugs as observed in our laboratory. The latter enzyme is also inhibited by naphthoquinone (*cf.*, Ball *et al.*[38]). Working further in this direction, it has been noted by Dutta [39] in the Bengal Immunity Research Institute that quinine inhibits the enzyme system responsible for the transformation of α-keto glutarate to succinate in Krebs cycle. This enzyme system is known to contain an active sulphydryl group and has been further observed that the above inhibition by quinine can be partially reversed by BAL, or, even sulphuretted hydrogen water. Question may be raised as to whether these point to the necessity of compounds capable of reacting readily with sulphydryl group? Any conclusion, however, would be premature, particularly as malarial parasites act through different enzyme systems.

It has been already mentioned that a biguanide, N^1-(6-methoxy-8-quinolyl)-N^5-p-methoxy phenyl biguanide, exerts the characteristic antimalarial activity but the N^1-(6-methoxy-8-quinolyl)-N^3-p-methoxy phenyl guanidine is inactive. In our study with succinic dehydrogenase we find that the former has got a high inhibiting action on succinic dehydrogenase whereas the latter has little action. A study with the enzyme system thus, apparently, tends to offer a clue to the problem, but it is to be remembered as the antimalarial-malarial parasites relation is a very complex one, it would be difficult to arrive at any conclusions without thorough and extensive investigations in diverse directions. We know that paludrine, an active antimalarial, exerts no action on the malarial parasites *in vitro*. Its *in-vivo* activity must then be due to some meta-

bolic change. Quite curiously, we have noticed[34] again that the supposed metabolite, the diamino triazine derivative, has no better inhibitory action at least on enzyme succinic dehydrogenase than the parent compound, paludrine or quinine (Vide Table II).

TABLE II

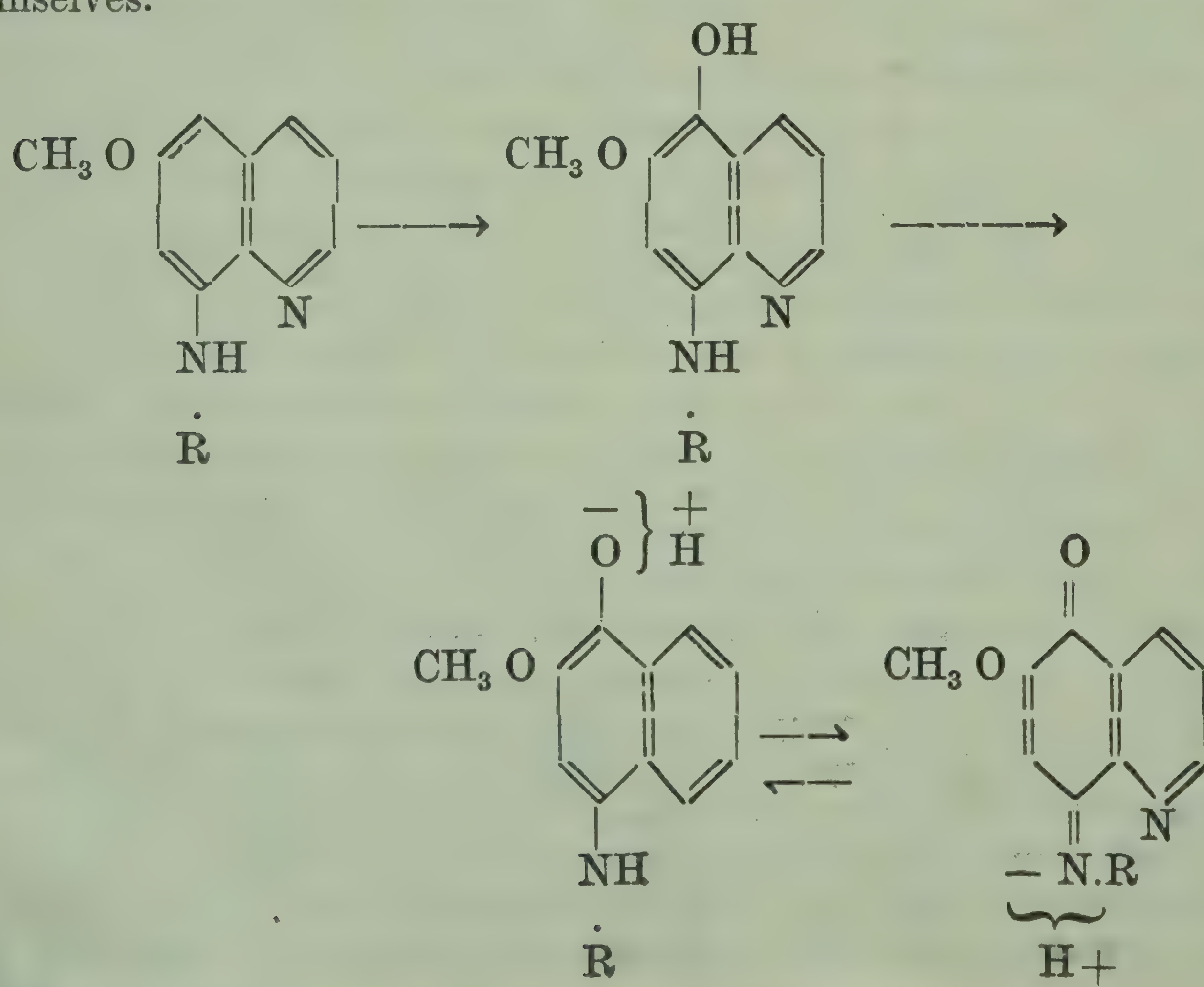
Drug	Concentration	Reduction time of Methylene Blue (1 : 10,000) in Minutes.	
		Drug	Control
Triazine Derivative*	2×10^{-4} M	7	7
Paludrine	Do.	11	8
Quinine	Do.	20	10

*1 : p-chlorophenyl-2 : 4-diamino-1 : 6-dihydro-6 : 6-dimethyl-1 : 3 : 5-triazine.

Obviously, the supposed metabolite of paludrine is again acting through a different enzyme system. This, therefore, warrants further study. Schmidt[40] and his collaborators have also shown that the activity of the triazine derivatives is not of any high order when assayed against *P. cynomolgi* infections in the rhesus monkey. It is to be noted that the mode of action of the majority of antimalarials is still obscure.. Many of the antimalarial drugs might interfere with a number of reactions essential for the metabolism of the parasites but it is to be shown that such an inhibition is responsible for their antimalarial reaction (*cf.* King and Wright[41]). In any attempt to understand the way in which an antimalarial drug may act on the malarial parasite, a knowledge of the metabolic process characteristic of all stages of malarial plasmodia and then, the morphological changes induced in malarial parasites by a drug, is necessary. The work so far carried out on the morphological changes in malarial parasites, tends to show that a considerable number of drugs of widely differing chemical constitution exerts an influence on the erythrocytic stages. The exo-erythrocytic forms of certain parasites can be destroyed by 8-amino quinolines, hydroxynaphthoquinones, biguanides and sulphonamides; whereas the gametocytes are directly attacked by 8-amino quinolines only. Several hypotheses have, however, been placed from time to time and these have enabled the workers in the line to make a fresh attempt for the synthesis of newer type of compounds. The antimalarial activity of quinine and methylene blue has led to the synthesis of plasmoquin. The latter has given rise to atebrin and chloroquin. The biguanides, pyrimidines and the triazine antimalarials are again outcome of the study on the nutritional requirements of the malarial parasites. The difficulty has always been with the observations from *in vitro* to *in vivo* studies. Quinine changes to a 2-hydroxy derivative but the latter is not the active product. Plasmoquin is believed to be oxidised to 5-hydroxy derivative and it has been shown that 5-alkyl or aryl derivative exerts no antimalarial activity. Paludrine is not so active *in vitro* and it may be said now that it undergoes a metabolic change to give some other product more active against the parasites[32]. The 6-methoxy 8-amino quinolines have been found to be more inactive *in vitro* in comparison with the corresponding 6-hydroxy derivatives, although the latter bodies exhibit *in vivo* little or no activity against tissue forms of *P.vivax* (cf., Alving [14] and Greenberg[42]). The *in-vitro* inactivity of pamaquin or pentaquin suggests that the antiplasmodial activity of these compounds is associated with the metabolic intermediates. Schonhoffer[43] has postulated that the antimalarial activity can be expected only

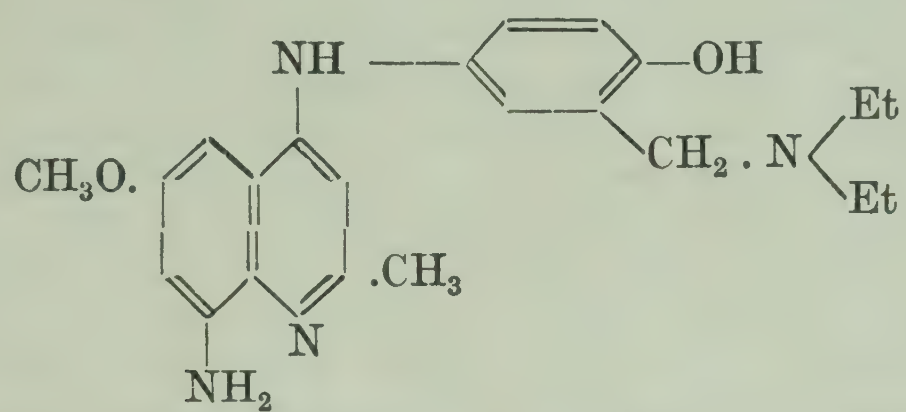
of those 8-aminoquinolines which can undergo biological oxidation to quinonimines and quinones. The 8-amino quinolines have been found not to possess the marked antimalarial activity associated with the drug *in vivo*. Josephson, *et al.*[44] have shown that pamaquin undergoes a metabolic degradation to a product more active *in vitro* and showing characteristic of a 5:6 quinoline quinone. Of course, the side chain of pamaquin may also undergo some oxidative change (*cf.*, Titus[45]). It is believed that the elucidation of the metabolic fate of these compounds will materially assist the rational development of more effective and less toxic curative antimalarial drugs. The work so far carried out tends to establish that the *in vitro* activity of 8-amino quinoline is due to its oxidative changes and one of the products of degradation must at least be 5:6-quinoline quinone (*cf.*, Drake[46] and Josephson[47]). The 5 or 7-hydroxy derivatives would be more susceptible in such transformation and as a matter of fact 5-hydroxy-6-methoxy-8-(*iso* propyl amino amyl amino) quinoline has been found to be more active than the corresponding 6-methoxy-8-(*iso*propyl amino amylamino) quinoline, and 5:6 -dihydroxy compound has been isolated from animals treated with 6-methoxy or even 6-hydroxy-quinoline. An additional methoxy group in the 5 position on the quinoline ring increases the toxicity of the drug (Alving[14]). It is obvious that active degradation product of pamaquin is not a 6-hydroxy compound. But since 6-methoxy-8-aminoquinoline derivative (pamaquin) is inactive against tissue forms of *P. gallinaceum in vitro* (*cf.*, Tokin[48]), so the activity of pamaquin *in vivo* must be attributable to some of its biological degradation products. The problem now is what is this product?

The quinoline derivative like quinine may also be oxidised to the 2-hydroxy compound. But the carbostyril derivative from quinine as well as from a 8-aminoquinoline is less active than the parent compound. Further, as substitution at the 5 position of pamaquin by an alkyl or aryl group annuls its antimalarial activity, the biological degradation product from 6-methoxy-8-aminoquinoline may be some quinonimine (*cf.*, Schonhofer[43]), a type of compounds which might exert an antimalarial reaction by themselves.



A compound of this nature would also easily react with sulphydryl group. This has already been postulated while discussing the drug-enzyme reaction at the earlier part of this address.

In course of our investigation with 8-amino quinoline derivatives we have to synthesise various derivatives in the light of the above metabolic degradation of the heterocyclic ring. Blocking the 2-position by a methyl group, keeping the 5-position free for metabolic changes and the 8-amino group of the quinoline nucleus unsubstituted, we have obtained compounds of the type:



This compound from preliminary screening tests with *P. berghei*, *P. relictum* and *P. gallinaceum* is being found to possess definite antimalarial activity. The ratio between effective and the toxic dose is considerably low. It would be of considerable interest to study its efficacy in human malaria. It may be further noted that its effect on pyruvic acid oxidation is almost similar to that of quinine in inhibiting the oxygen consumption.

The inertness of the triazine derivative as has been isolated during the studies on metabolites of paludrine in such type of inhibition, raises a fresh problem of investigation. More than 12 dozen compounds of triazines have been previously studied in vain but this triazine is of somewhat different type and study with this series of compounds might be of some added interest. As a matter of fact, it has been found[49,50] in our hands that 2:4-diamino-1-p-sulphonamidophenyl-1:6-dihydro-6:6-dimethyl-1:3:5-triazine is practically non-toxic and is effective against *P. berghei* infection in mice of average weight 15 to 20 g. at a dose level of 15 mgm per Kilo; whereas in case of quinine and paludrine it comes to 75 and 9 mgm per Kilo respectively. The Table III would give an idea of the activity.

TABLE III

PARASITES USED : PLASMODIUM BERGHEI
ANIMAL: MICE OF AVERAGE WEIGHT 20 GM.
INOCULUM INJECTED : 1 MILLION INFECTED R.B.C./G. INTRAPERITONEALLY.

Drug.	Dose in mgm.	Days of Prepatent parasitemia.	No. of infected r.b.c. out of 500 r.b.c.	Distribution of parasites by stages of growth.
Quinine	1.0(0)	2.(2)	12(183)	Unsegmented forms.
	1.5(0)	4 (2)	7(300)	,,
	2.0(0)	5 (2)	16(220)	,,
Paludrine	0.15(0)	3 (2)	43(210)	All forms (Rings in excess).
	0.2(0)	3 (2)	10(290)	Unsegmented.
	0.25(0)	3 (2)	10(290)	,,
Triazine Derivative	0.3(0)	2 (2)	42(200)	Distorted rings.
	0.5(0)	2 (2)	20(200)	,,
	1.0(0)	4 (2)	6(220)	Unsegmented.
	2.0(0)	4 (2)	3(282)	,,

Figures in parenthesis are for control experiments.

In all control experiments the presence of parasites in all stages of growth was noticed in plenty.

All these tend to show what amount of investigations would still be necessary for the evolution and the commercial production of an antimalarial of choice.

Need for Consolidated Development

For any material progress of the country we will have to offer the millions food as well as armaments to fight against disease. In both the spheres chemists and chemical engineers will have to play a greater role. The Planning Commission has placed the Government's plan for investment in industry and has already fixed the targets of production of various chemicals like superphosphate, ammonium sulphate, glass materials, acids, soda ash, caustic soda, salt, paper etc. In pharmaceutical lines preference has been given for the production of insecticides, antibiotics, sulpha drugs, anti-leprosy and anti-dysenteric drugs. It is true that we cannot expect better production if millions suffer from either nutritional or communicable diseases. For controlling any such disease, say bacillary dysentery infections, we may need 80,000 lbs of sulfadiazine and 20,000 lbs of sulphanilyl benzamide (*cf.*, Basu [51]). For the treatment of leprosy we would now require for each patient about 2 lbs of the drug, diamino diphenyl sulphone. In controlling mortality from tuberculosis we may need thousands of pounds of thiosemicarbazone or hydrazine drugs. It is believed that at least one in every one hundred and forty of us is infected with tuberculosis. If then, we even make an attempt to treat at least 1 million patients suffering from tuberculosis with any new synthetical anti-T.B.—drug, quite a large number of chemicals would be required (*cf.* Basu[52]). It can be easily imagined what amount of inorganic and organic chemicals would be necessary for the production of various drugs and pharmaceuticals which the Planning Commission has envisaged. Steps for actual production of all necessary meterials are to be taken. These may involve chemical, mechanical, electrical and allied processing. Another aspect of the problem involved in fine chemicals and pharmaceutical industry is often ignored and this is on the requirements of various accessory materials so essential for placing a product in the street corner shop for dispensing to the suffering and/or consuming public. Glass, rubber, cork, linen, oily materials, geological products and many others of standard quality would be in demand to meet the requirements. These again tend to show what amount of consolidated development is essential for a full fledged growth of fine chemical and pharmaceutical industry.

Many of the audience perhaps do not know the tragedy of many young lives cut off in their prime by an attack of tetanus or diphtheria during the first World War; similarly in view of flooding of the market with various foreign products at the moment it is difficult to believe that India produced a considerable amount of her requirements during the World War II. The Pharmaceutical Industry has made a progress during the last two decades. But for better expansion the manufacturing concerns are to direct their activities more to the promotion of different varieties of products and specially to research work on new products. It is, however, to be noted that the advance made in any drug research and chemical industries in foreign countries is mainly due to the healthy co-operation amongst the various scientists following the profession of chemical science on the one hand and biological sciences on the other. Further, it is to be noted by all that the first few years of manufacture of any chemical seldom yield profits and the productions have to be carefully nurtured to get a momentum for its growth. Without a sense of patriotism and of national pride, it would be difficult to develop

any industry and without a similar sense being aroused in the minds of those who hold the purse-strings of finance as well as of those who are controlling the state policies, it would be a dream to think over self-sufficiency in essential requirements of our country.

A word be added now on pure research, i.e. a research not intended to provide some product or gadget that has any sales potential but one which is solely for the purpose of extending the frontiers of human knowledge. Pure research is actually the source of all our present technology and industrial achievement. It may be remembered that at the back of every commercial product made and sold by industry, there lies a long list of data carefully collected by a group of men,-humble scientists,—working in obscurity and in their laboratories, often un-noticed and without acclaim or recognition during their entire life-time. Any financial support to such a student of pure science may have no direct and/or tangible benefits to the donor, but the intangible return is incalculable. In the words of Sir J. J. Thompson pure science is the seed of applied science and to neglect pure science would be like spending a very large amount of manuring, and ploughing the land, but to omit the sowing of any kind. It is difficult to induce into the minds of businessmen as well as politicians the need for supporting a work where there appears not the slightest chance of some immediate practical application and/or, materialistic gain. The country needs a band of philanthropic industrialists and capitalists who would not grudge to allocate funds to a silent, sincere and honest worker for collecting and recording some data which on integration in future will alter the trend of civilization and/or path of human knowledge. Whatever has been expressed so far, demands an adjustment in the elements of our human character. For such achievement, education is necessary from the very early stage of training for creating a co-operative mind with a national outlook.

Formation of a Board for Co-Ordination

It appears, therefore, that in taking to a profession of science in industry one has to learn the fundamentals of his particular branch of science and technology, a clear conception of modern trends in economics and a deep appreciation of human relationships so that he may be useful in a costly business for industry. Such requisites demand that the University should have visiting lectures from industry and industry might similarly send members of technical staff to universities for refresher courses. On the other side, there should be a close co-ordination of the different Ministries—Commerce, Finance, Health, Education and Industry, of the States as well as of the Union as has already been recommended by the Fiscal Commission. All these bodies should remain in constant touch with the developmental work of the industries. The Tariff Commission might help in guiding the trends of future production and the Development Council formed under the Industries Act, 1949, would certainly suggest the forms of efficiency for all-round industrial progress. A better policy still seems to be to set up a small liaison committee of each major industry consisting of leading technical men of the Industry, representatives of the University faculties responsible for the studies appropriate to that industry, and suitable persons from the Directorates of relevant departments of the States. A direction from such a body with an administrative head, or Chairman will be more helpful and offer methodical guidance by pointing out that concentration on too many items in too small units, is detrimental to the advancement of technical learning as well as to the growth and expansion of industries. Such a Board may also suggest newer

channels of industries and thereby, help in shaping Indian industries to the best advantage of the society and the country. Science cannot exist in isolation but must take into account its relationship with industry and society in general.

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40th INDIAN SCIENCE CONGRESS, LUCKNOW, 1953

SECTION OF GEOLOGY AND GEOGRAPHY

President:—N. L. SHARMA, M.Sc. (B.H.U. & Liv'pl), M.M.G.I., F.G.M.S., M.I.S.E.

Presidential Address

Problems in the Correlation of the Pre-Vindhyan Igneous Rocks of Rajasthan.

I deeply appreciate the great honour which the Indian Science Congress Association has conferred on me by electing me to preside at this Section of Geology and Geography. On looking back at the past sessions of the Congress, I find a brilliant galaxy of my predecessors, some of whom have been the real makers of Indian Geology, and on looking ahead, I find there are far more qualified members who could have discharged the presidential responsibility more efficiently than myself. However, I accepted the office, fully conscious of my own limitations, because I felt it is not only a great honour to me personally, but also to my Institution, Indian School of Mines and Applied Geology, which has been called upon to supply three Presidents to this Section during the last twenty three years.

I have selected for to-day's Address, a subject which draws our attention to some of the problems which still await solution, regarding the correlation of the pre-Vindhyan igneous rocks of Rajasthan, with the geology of which I am a bit familiar, in as much as, it was in Danta State (a border state, at that time in Gujrat) that I had my first initiation in field geology under late Prof. K. K. Mathur. Some of these problems, when rightly solved, are likely to have a great bearing on the correlation of the sedimentaries of Rajasthan and the adjoining region to the south.

I. PRE-VINDHYAN FORMATIONS OF RAJASTHAN

Our present knowledge of the Rajasthan geology is mostly based on the works of Dr. A. M. Heron, Mr. B. C. Gupta, Mr. P. N. Mukerjee, Dr. A. L. Coulson, Dr. P. K. Ghosh, Dr. J. B. Auden, Dr. H. Crookshank and others. Dr. Heron spent in Rajasthan, during his service in the Geological Survey of India, more than twenty field seasons; and so, he may be regarded as an authority on the geology of this state.

According to Heron (1935, p. 17), Rajasthan can be divided into four geological and physiographical regions, of which the eastern region consists mostly of the Vindhyans, some little altered Archaeans and some Deccan Trap; and the western region, of sandy plains with scattered outcrops of Malani volcanics, Vindhyans, Mesozoics and Eocene. The remaining two regions are the central plain, composed of Aravalli and pre-

Aravalli gneisses, and the hilly tract occupied largely by the synclinorium of the Delhi system. It is these regions, which are the most important from the geological, stratigraphical and petrological points of view and they comprise parts of Ajmer-Merwara, Jodhpur, Udaipur, Sirohi, Palanpur and Danta states (the last two states being now again included in the state of Bombay).

The important pre-Vindhyan geological formations of Rajasthan are tabulated in the following Table, based on the work of the Officers of the Geological Survey of India.

TABLE SHOWING THE PRE-VINDHYAN FORMATIONS OF RAJASTHAN.

Post-Delhi Igneous Rocks	Post-Erinpura-granite (Pre-Malani)	Gabbros (picrites & olivine-gabbros) dolerites (olivine-, hypersthene-olivine-, biotite-), basalts (hornblende-, augite-, olivine-), pyroxenites, epidiorites, soda-syenite.
	Erinpura granite	Quartz veins. Pegmatites & aplites; quartz-felspar porphyries. Erinpura granite.
	Pre-Erinpura-granite	Epidiorites, amphibolites, hornblende-schists, actinolite-schists, tremolite-schists, talc-chlorite schists, talc-limonite-serpentine rock, gabbros, dolerites, granulites.

	South-west Aravallis.	North-east Aravallis.
Delhi System	Calc-gneisses & calciphyres. Calc-schists. Biotite-schists & phyllites with *amphibolitic rocks.*	Ajabgarh series:— Biotite schists, phyllites, quartzites & impure biotitic limestones & calciphyres with basic tuff or volcanic dust (*epidiorites*).
	—— Absent ——	Hornstone breccia.
	—— " ——	Kushalgarh limestone.
	Quartzites. Arkose grits and conglomerates.	Alwar series:— Quartzites, arkose conglomerates and mica-schists, with bedded lavas altered to *epidiorites*.

— Unconformity —

Raialo Series	Garnetiferous biotite schist. Marble and limestone. Quartzite.

— Unconformity —

Post-Aravalli Igneous Rocks	Soda-syenites and soda-pegmatites. Quartz veins. Pegmatites and aplites. Granites. Epidiorites, hornblende-schists, actinolite-tremolite schists, talc-serpentine-chlorite rocks.

Aravalli System	Badesar quartzites, Kanoj and Khardeola grits. Khairmalia *amygdaloid.* — Unconformity (Uncertain) — Ranthambhor or Mandalgarh quartzite with *dolerite* sills. Thick succession of shales, slates, phyllites and mica-schists with local quartzites and limestones. Thin ferruginous limestone. Thin basal quartzite or conglomerate, often with arkose. *Volcanic beds.* (local).

— Unconformity —

Pre-Aravalli Formations.	Banded Gneissic Complex	Quartz veins. Pegmatites and aplites. Amphibolitic rocks. Biotite-granite. Bundelkhand (Berach) granite. Biotite and chloritic schists and quartzose bands.

From this Table, it appears that in Rajasthan we have three acid igneous activities and four basic igneous activities before the Vindhyan period. The former are represented by the pre-Aravalli, post-Aravalli and post-Delhi (Erinpura) granites, and the latter, by pre-Aravalli, post-Aravalli, post-Delhi (pre-Erinpura-granite) and pre-Malani (post-Erinpura-granite) basic rocks. In addition to these, there had been some basic intrusions or extrusions contemporaneous with the deposition of the Aravalli and the Delhi sediments. There had also been two periods of intrusions of alkaline magma—one, post-Aravalli and another, pre-Malani (post-Erinpura-granite). We shall now discuss the problems connected with each of the major groups of igneous rocks.

II. PRE-ARAVALLI IGNOUS ROCKS

(i) The Bundelkhand (Berach) Granite

Heron regards the Bundelkhand (Berach) Granite of Mewar as pre-Aravalli (pre-Dharwar) and the oldest rock in Rajasthan and hence of India, for all the gneisses of the Peninsula which were considered as pre-Dharwar, are now regarded as post-Dharwar in age. Many geologists do not consider the Bundelkhand Granite to be the oldest rock formation of India. Fermor (1909, p. 237) had regarded Bundelkhand Granite to have intruded into the Dharwars subsequent to the folding of the latter. Krishnan (1943, pp. 125 and 135) says that this formation resembles the younger granites (Bellary gneiss, Closepet granite, Dome gneiss, etc.) rather than the gneisses of the other Archaean areas of Peninsular India. He has, therefore, assigned in his table giving the rough correlation of the Peninsular Archaeans, two positions to the Bundelkhand Gneiss of Rajasthan—one, below the Aravallis and the other, same as that of the much younger granites mentioned above. Regarding the Berach Granite of Mewar which is regarded as equivalent to the Bundelkhand Granite of the type area by Heron, Pascoe says (1948, p. 248), "In its 'greasy' character, the opalescence of its quartz, the scantiness of its ferromagnesian constituents, and the usually decomposed condition of the latter and of its felspars, the Berach rock is curiously reminiscent of the Champion Gneiss of Mysore, though shearing and crushing seem to have been less in Rajputana rock".

During recent years, Misra and his students (1948, 1949 and 1952) have carried out a detailed geological study round the towns of Mahoba and Kabrai on the north-eastern edge of the great batholithic intrusion of Bundelkhand Granite of the type area, and have discovered in it numerous xenolithic masses of older rocks, like quartzites, jasperised quartzites, argillites, hornblende-biotite schists and amphibolites. The outcrops of these xenolithic masses, though detached, can be measured in tens of feet, and they show a constant dip and strike. These workers regard the Bundelkhand Granite as an intrusive rock and post-Aravalli in age.

(ii) The Banded Gneissic Complex

There seems to be a little anomaly between the stratigraphical position of the individual members of this Complex, as given in my table after Pascoe (1950, p. 247) and that shown by Gupta (1934, p. 111), who gives the following order in the table of formations present in Central Mewar.

Pre-Aravallis.	Gneissic granite.	
	———————— Intrusive break ————	
	Banded gneissic complex.	Bundelkhand Gneiss.
	Para-gneiss.	
	Biotite schist.	
	Quartz veins.	

Pre-Aravallis.
- Pegmatite.
- Granite.
- Aplite.
- Amphibolite (Epidiorite).

It may be pointed out that in the map accompanying his Memoir, Gupta has shown the para-gneiss as Aravalli and not as pre-Aravalli as shown in the above table. Otherwise also, it appears that the rock types of the Complex, given above, have not been shown by Gupta in proper sequence, and we have to recognise Pascoe's stratigraphical order as more representative, for Heron (1935, pp. 21-22) concludes, "bosses of granite in which the rock is little foliated represent solidified 'cisterns' and that the foliated and banded gneissic veins are apophyses from them. Pegmatites and aplites, closely related to the granite occur in it as veins and also invade the schists and granite gneisses forming with them composite gneisses. They probably belong to various ages. Epidiorites and hornblende-schists representing basic intrusives occur in abundance and are permeated by aplites and pegmatites. They occupy, for the most part, an intermediate position in the sequence of intrusion, invading the granite and gneissic granite and in their turn cut by pegmatites and aplites". Again, according to Pascoe (1950, p. 252), "in many cases, the pegmatites appear to have detached sheets of the gneissic granite which now lie as isolated masses along the borders of the intrusions. With the gneissic granite, and to a less extent with the hornblende schists, the aplites and pegmatites have produced composite gneisses of very variable aspect. The period of intrusion of these pre-Aravalli aplites and pegmatites, appears to have a much wider range than that of the granites, although the close relationship between all three is seen in the free occurrence of the two former as syngenetic veins in the last."

From the above quotations of these two authorities, it appears to me that pegmatites and aplites cannot be regarded as genetically connected with the granite, for then, it is difficult to account how there had taken place an intrusion of a basaltic magma after the consolidation of the granitic magma, but before the intrusion of the residual liquids from the latter. Moreover, according to Heron (1936, p. 53) himself, some of the epidiorites and hornblende-schists which are abundant in the extreme south-west in mixed gneisses of the Central Mewar plain which underlie the Aravallis, doubtless represent post-Aravalli dolerites and basalts. Further, the so-called pre-Aravalli pegmatites resemble the post-Aravalli ones, in generally containing no tourmaline and muscovite, which two minerals are common constituents of post-Delhi pegmatites (Pascoe, 1950, pp. 252 and 262). It thus appears to me that we have here an example of an area where extensive granitisation had taken place by these pegmatites and aplites, possibly in post-Aravalli period. In support of this view, it may be mentioned that Crookshank (1948, p. 109) does not agree

with the views of Heron and Gupta that the Banded Gneissic Complex of northern Mewar differs essentially from the Aravalli schists and according to him, the former has been formed by the intrusion of pegmatitic and granitic material into the Aravalli schists on a large scale.

Bhola (1952), who had an opportunity of examining the succession of the Delhi System and the outcrops of the pre-Delhi rocks exposed on either flank of the Delhi synclinorium during his survey of the economic minerals of Jodhpur and Ajmer, is of opinion that the banded gneisses in this region mapped by Heron as pre-Aravalli gneisses, are really highly metamorphosed and granitised Aravallis. Both on the north-west flank and south-east flank of the synclinorium, e.g., in Sojat (Jodhpur) and Srinagar (Ajmer) areas, patches of biotite-schists have been found on careful search, and a gradation between the biotite-schists and biotite-gneisses has been traced. Further east of the synclinorium in the flat country as far east as Tonk, Heron has mapped the entire area as covered by pre-Aravalli or pre-Delhi gneiss, with the exception of the Malpura-Rajmahal-Sawar outcrop of Delhis; but according to Bhola, "this region is covered with a big expanse of alluvium and the only exposures are in mica mines and stream or well cuttings, and they show all gradations of rocks from biotite-schists to biotite-gneisses. Here also, the variation can be attributed to extensive granitisation of the original biotite-schist which most probably belongs to the Aravallis, as further east, these rocks appear to pass gradually into less metamorphosed slates and phyllites of Bundi area, which have been assigned by Coulson to the Aravallis".

From the above observations, it appears that the Banded Gneissic Complex, like the Bundelkhand Granite, is also to be regarded as post-Aravalli and hence post-Dharwar in age.

III. POST-ARAVALLI (PRE-DELHI) IGNEOUS ROCKS

(i) The post-Aravalli and Aravalli Basic Igneous Rocks

According to Heron (1935, p. 24), epidiorites and hornblende schists, metamorphosed ancient basic rocks, and the much newer post-Delhi dolerite had invaded the Aravallis, but they are much scarcer among them than in the younger Delhis or in the older pre-Aravalli gneisses. For this curious fact, he does not give any reason. In addition to these post-Aravalli metamorphosed types, Heron (1922, p. 135; 1936, p. 51) has described sills and dykes of dolerite and basalt in Ranthambhor quartzite in Jaipur and Mandalgarh quartzite in Mewar. The dolerites show ophitic texture and though plagioclase felspar is much decomposed into kaolin and sericite, augite is little altered and in certain specimens, olivine is present and is altered only along cracks. Heron has correlated these dolerites with those of the Gwaliors (a facies of Aravallis, according to him). In the geoological map of south-eastern Mewar, he has shown the stratigraphical position of this dolerite between Ranthambhor quartzite and the overlying Khairmalia amygdaloid which is a purple black fine-grained volcanic rock, with numerous spherical or slightly flattened

vesicles, some as large as cherries or almonds, containing banded chalcedony or crystalline quartz or calcite with central cavities. Heron (1936, p. 42) regards this rock as the effusive representative of the hypabyssal dolerite dykes and sills mentioned above. The presence of unaltered olivine in the dolerite and that of vesicles and glass in the volcanic rock, suggest the possibility of their being younger than the post-Aravalli (pre-Delhi) basic rocks which are generally changed into epidiorites and hornblende schists. In this connection, it may be interesting to note that the Ranthambhor quartzite, in which also occur the dolerite sills, of Jaipur and the underlying shales and slates of that area, were formerly regarded by Heron to be Delhis and not Aravallis, for he (1935, p. 25) writes: "On my first visit to the south-eastern Jaipur, I believed that I could trace a gradual increase in the metamorphism of these Gwalior type shales and slates across the strike to the north-west into the typical Aravallis; on my second visit, with Hayden, Middlemiss and Vredenburg, I was shaken in my opinion, more perhaps by the weight of their opposition to it than by actual conviction on my part and classified these rocks as Gwaliors. Since then, having had access to the wide expanses of them in Mewar, I am convinced that my original opinion was correct and that the Gwalior type shales of south-east Jaipur, Bundi and south-east Mewar and the typical Aravalli phyllites and mica-schists are all the same, varying only in their degree of metamorphism". This view has led finally to the Gwalior series, which was so long considered as Purana, to be now regarded as corresponding to only the upper part of the Aravalli sequence (Pascoe, 1950, p. 288). A detailed study of the basic rocks associated with the upper part of the Aravallis mentioned above, as well as, those of the Gwalior series proper, and their comparison with the post-Cuddapah basic rocks of other areas may throw fresh light on the true stratigraphical position of these formations.

The talc-serpentine-chlorite rocks which occur in the extreme south-west of Mewar and also in Dungarpur and Idar, are considered to be highly metamorphosed ultrabasic intrusions (dykes and sills) of peridotite or pyroxenite. Middlemiss (1921, p. 103) describes them as being constantly associated with the Delhi quartzite. But what was mapped as Delhi quartzite in Idar by Middlemiss, is now regarded as Aravalli quartzite by Heron and hence, according to Ghosh (1933, p. 451), these intrusions are presumed to be pre-Delhi in age. Ultrabasic rocks represented by talc-schists and chloritie-schists in south-west of Beawar and small plugs of unfoliated talc-limonite-serpentine rock with veins of magnesite in Ajmer, are regarded to be post-Delhi in age (Pascoe, 1950, p. 386). In view of the doubt raised by me in the succeeding paragraphs dealing with the post-Aravalli granite, about the correctness of Heron's inversion of Middlemiss's sequence of sedimentaries in Idar, it may be that the ultrabasic rocks of Mewar, Dungarpur and Idar, may also turn out to be of

the same age as those of Ajmer-Merwara, or the latter may themselves be pre-Delhis as suggested in this address further on.

(ii) The Post-Aravalli Granites

The Aravallis of Rajasthan are universally accepted as equivalent to Dharwars of the rest of Peninsular India. Heron (1936, p. 51) has suggested that the Aravallis may be considered as analogous, if not contemporaneous, with the Dharwars of South India from lithological considerations. In South India, Dharwars are the oldest rocks exposed and it is now believed that there have been only two granite intrusions—one, represented by Peninsular gneiss and the other, by Closepet, Bellary, Hosur and Arcot granite. The Champion gneiss, which was regarded as the earliest acid intrusive into the Dharwars, is not, according to Pichamuthu (1951, p. 44), a well-defined type either petrologically or stratigraphically, and it is not recognised now as a separate unit. In any case, all these granites are post-Dharwar in age. It is rather surprising that the post-Dharwar (but pre-Cuddapah) granite intrusions which are so widespread throughout the rest of Peninsular India, are according to the work of Heron and others, very limited in extent in Rajasthan, where the post-Delhi Erinpura granite is wide-spread but not so the post-Aravalli (pre-Delhi) granite. One does not find any occurrence of this granite marked on the Geological Map of Rajasthan by Heron, recently published in the Manual of the Geology of India and Burma by Pascoe. However, the existence of this granite in many areas in Rajasthan is clear from the text of the book. In the early years of his survey of north-eastern Rajasthan, Heron (1917, pp. 15-22 and 92-98) had described and mapped two types of granites—one, under pre-Delhi (Aravalli) rocks and the other, under post-Delhi intrusives. As the field party proceeded southwards towards Mewar, the former pre-Delhi (Aravalli) granite seems to have been lost sight of or regarded as pre-Aravalli, till finally, in Central Mewar and south-eastern Mewar, we find only the pre-Aravalli granite and banded gneissic complex. Of the few exposures of pre-Delhi granite shown on the geological map of Central Mewar by Gupta (1934) as intrusive into the Aravallis, those in the northern area have been actually described in the text of the Memoir by him (Gupta, 1934, pp. 131 and 155) to be part of Banded Gneissic Complex and those to the south are correlated to Erinpura Granite. So actually, there is no post-Aravalli (pre-Delhi) granite in this part of Rajasthan. While the field party of the Geological Survey of India was proceeding towards south-west from north-eastern Rajasthan, the geological survey of Danta state (then in N. Gujrat, lying at the south-western extremity of Rajasthan) was completed by me (Sharma, 1931, pp. 1-28) and I correlated the sedimentaries—calc-gneisses, crystalline limestone and marble—of the state with those of the neighbouring Idar state surveyed earlier by Middlemiss (1921), and regarded them as Aravallis. I mapped in Danta state three types of gra-

nites—post-Aravalli granitoid and schistose gneisses, post-Delhi (Erinpura) granite, and microgranite and granite porphyry. In a subsequent paper, Sharma and Purkayastha (1935, pp. 369-375) examined the heavy minerals of the post-Delhi granites and micro-granites of Danta state, which were found to confirm my earlier suggestion that both might be co-magmatic. In the field season of 1933, Ghosh mapped the small states of Sudasna, Umbri, Bhalusana, Satlasna, etc., which lie just south of Danta state. It will be relevant for subsequent reference to quote here from the report of Fermor (1934, p. 70), the then Director of the Geological Survey of India, about the geology of these states:

"The formations met with were alluvium, the Jalor or Idar granite, the Erinpura granite, calc-schist (Delhi) and fine-grained granite gneiss. The *granite gneiss* is found at the boundary of Danta state and the small states of Umbri and Bhalusana. It is a finely banded biotite-granite-gneiss, and agrees in character with some of the fine-grained varieties of Mr. N. L. Sharma's 'granitoid and schistose gneisses' described in connection with the geology of Danta state. According to Dr. Ghosh, this gneiss is definitely older than the Erinpura granite, as it is found as inclusions therein. Owing to the lack of exposures, its relationship to the calc-schists, the oldest sedimentary rocks of this locality, is not known. Dr. Ghosh, however, provisionally regards this gneiss as pre-Delhi in view of the fact that nowhere in the whole of western Rajputana have the Aravallis so far been found to be intruded by a granite older than the Erinpura granite. Similar pre-Delhi gneiss has been found by Dr. Heron in Jodhpur state, to the north-east".

In the meanwhile, Coulson (1933, p. 12) had completed the geolocal survey of Sirohi state, just north-west of Danta state, and had mapped there two granites—one, Erinpura granite, and the other, Idar granite, younger than the former and regarded to be the plutonic facies of the Malani volcanic rocks. In 1935, Heron proceeded to Danta state which had by then come under western Rajputana States Agency. The *geological importance* of this state has been referred to by Heron (1936a, pp. 68 and 69) in the following words :

"This had previously been geologically surveyed extra-departmentally by Mr. N. L. Sharma, but its resurvey was necessary as it forms a link between the surveys of Middlemiss in Idar state, Coulson in Sirohi state, P. K. Ghosh in Idar and Palanpur states, B. C. Gupta and P. N. Mukherjee in northern Bombay and Heron in Mewar. It happened in fact to be the 'keystone in the arch' of the geology of Rajputana and northern Bombay, which Dr. Heron and his colleagues have brought to completion in the field season under review".

It may be mentioned here that in 1931, as a result of the connection established between his survey in Mewar and Ajmer-Merwara and that of Middlemiss in Idar, Heron (Fermor, 1931, p. 143) came to the conclusion that Middlemiss scale of formations, as far as the metamorphic rocks of

Idar were concerned, was reversed, though the relative order given was correct. Thus, the Aravalli series of Middlemiss in Idar state, consisting of a mixed complex assemblage of foliated crystalline rocks—calc-gneiss, gneiss, biotite-gneiss, mica-and other schists, amphibolite limestone, etc.—was regarded as the Ajabgarhs, and the Delhi quartzite and phyllite series of Middlemiss as Aravallis. The Idar granite, which was regarded by Middlemiss as equivalent to Jalor and Siwana types, has now come to be recognised by Heron as Erinpura granite.

The fundamental difference in my interpretation (Sharma, 1939, p. 420) of the geology of Danta state and that of Heron, is as follows :

(a) Heron (1936a, p.69) regards as post-Delhi granites, not only the fairly homogeneous, coarse, porphyritic, biotitic granite of the typical Erinpura type, but also, the fine-grained, non-porphyritic, less biotitic and more variable types, often banded, streaky and foliated, which according to him, appear to be more in the form of sheet intrusions and are contemporaneous but on the whole slightly earlier than the coarse-grained material. On the other hand, I regard the above so-called 'slightly earlier' granites as post-Aravalli (pre-Delhi) in age, definitely older than the Erinpura granite.

(b) Heron regards the calcareous rocks (calc-schists, calc-gneisses and marbles) of Danta state as Ajabgarhs (uppermost Delhis), whereas, I regard them as Aravallis.

The above two interpretations are interconnected with each other. If we assume that the calc-series belongs to the Delhi System, there is then no other alternative left but to regard both the types of granites to be post-Delhi (Erinpura) intrusions and almost contemporaneous with each other; for both of them show intrusive relationship to the calcareous rocks and there has been no other acid phase of igneous activity after the Delhis and before the intrusion of Erinpura granite. Conversely, if we regard the two granites as of two different ages, then the calc-series must be regarded as Aravallis and cannot be Delhis.

The foliated and banded granite forms an almost continuous mass of intrusion, extending from north to south in the central portion of Danta state. Some of the highest hills and ridges like 'Sur', 'Dhamanawa', 'Ritaro' and 'Ghori' (local names), are made up of this granite. The lithological characters including weathering of this granite is quite different from those of Erinpura granite. Intrusions of typical Erinpura granite are common in this granite (granite-gneiss) and their junction is very sharp. For example, at the southern extremity of Danta state, north-west of Nedardi, a small *nala* marks the sharp boundary of the two granites. There is no gradation between the two types. Further north-west of this *nala*, near Vajasan, a big tongue of typical Erinpura granite from its main mass cuts across a small ridge of finely foliated granite-gneiss and there is no gradation between the two types here too. South of Danta state boundary, Ghosh, as referred to earlier, had found inclusions

of granite-gneiss in Erinpura granite and had suggested that the former was definitely older than the Erinpura granite.

All these facts prove that in Danta state, we have actually granites of at least two different ages—one, post-Aravalli (pre-Delhi) and the other, post-Delhi (Erinpura). In May, 1939, when Sir Lewis Fermor had visited India, I had written to him requesting him to visit Danta state once, before writing chapter 5 on the (Manganese Ore)-Marble Province of Rajputana-Gujrat for his Memoir (Vol. No. 70) on "An Attempt at the Correlation of the Ancient Schistose Formations of Peninsular India". In reply, he wrote that he would not have any opportunity of visiting the state and that the fundamental reason for the difference between my interpretation of the geology of the Danta state and that of Heron and Ghosh, appears to be in different interpretations of the age of the granitoid and schistose gneisses. I hope the Geological Survey of India will be able to get the problem regarding the age of the granitoid and schistose gneisses of Danta state thoroughly examined before the volume of Fermor's Memoir on the Rajasthan-Gujrat region is published. For, if these gneisses are proved to be pre-Delhis, then, the present views about the age of the sedimentaries, not only of this state but also of the adjoining states of Sirohi, Idar and Mewar, will have to undergo a radical change, which is likely to affect the geological history of this portion of Peninsular India.

(iii) The Post-Aravalli Pegmatites and Aplites.

Heron and Ghosh (1938, pp. 397-98) write about the acid igneous intrusions of Palanpur, Danta and part of Idar states as follows :

"Taking Rajputana as a whole, the intrusion of the Erinpura granite and its modifications appear to have lasted over an appreciable period of the tectonic history of the Aravalli range. .... The aplite or acid pegmatite veins which form interfoliar (*lit-par-lit*) injections in the calc-gneisses and the biotite schists are probably an earlier phase as they seem to be affected to some extent by the folding. At about this stage, are the banded and streaky larger sill-like intrusions of the Erinpura granite, often rather acid, which are typically developed in south-west Mewar. Then perhaps we have the larger fine-grained acid masses of the granite and the foliated, biotitic bosses, which grade into each other and into the slightly later unfoliated, coarse granite, the Idar granite of Middlemiss, which shows no signs of pressure. Later, probably are the large, well-crystallised dykes and sills of coarse pegmatite, bearing muscovite, tourmaline and beryl which show no compressive effects, sometimes cut through the granite and are independent of the structure of the rock through which they pass. Latest of all are the veins of quartz".

Thus, the order for Erinpura granitic intrusions, according to these authorities, can be tabulated as follows :

Quartz veins.
Pegmatites (coarse-grained and muscovite-bearing).
Erinpura granite (unfoliated and coarse-grained).
Fine-grained acid granite and foliated biotite granite.
Banded and streaky large sill-like granite intrusion.
Aplite and acid pegmatite veins.

In the case of pre-Aravalli Banded Gneissic Complex, Heron puts the pegmatites and aplites together and later than the pre-Aravalli granite, whereas, in this case the aplites and some pegmatites are regarded to be earlier than the granite and the coarse pegmatites, and all are of the same age, post-Delhi (Erinpura).

Earlier in this address, while discussing the pre-Aravalli gneissic complex, it has been pointed out by me that the pegmatites and aplites of that complex cannot be regarded as genetically connected with the so-called pre-Aravalli granite if there is an intrusion of basic rocks in between the two. Evidently, the aplites and acid pegmatites must be post-Aravalli in age. Middlemiss regards the aplite and pegmatite veins penetrating the calc-gneiss and biotite-gneiss of Idar state as post-Aravalli. Heron (1935, p. 24) also regards the post-Aravalli granite as an acid, fine-grained, aplo-granite, which also produces by *lit-par-lit* injections in the Aravalli mica-schists, a banded composite gneiss which runs as a broad band from Udaipur city southwards into Dungarpur state. It therefore, seems to me quite reasonable to expect that in the order of granitic intrusions given above (all of which are regarded by Heron as post-Delhi and Erinpura), we have probably two phases of intrusions connected with granites of two different ages; the lower ones of post-Aravalli (pre-Delhi) granite and the upper ones of post-Delhi (Erinpura) granite.

Again, Heron and Ghosh (1938, p. 398) say: "Though in Idar the granite is unfoliated and coarse in grain, we have in Danta, transitions from this later type to the finer-grained, more acid, foliated and streaky forms which are believed to have been earlier arrivals while cimpressive stresses were still in action". I have given the reasons in the above paragraphs why I regard these early arrivals, not as post-Delhi but as pre-Delhis and post-Aravallis, when not only in Rajasthan but even all over the Peninsular India, the compressive stresses were in action. With this assumption, the aplites and acid pegmatites of Idar are actually to be correlated with the above post-Aravalli (pre-Delhi) foliated granite of Danta state and not with the post-Delhi (Erinpura) unfoliated granite of Idar state.

(iv) The Post-Aravalli Soda-syenites and Soda-pegmatites

The soda-bearing rocks of Kishangarh are regarded by Heron (1924,

p. 181) to be pre-Delhi and later than the epidiorites, granites and pegmatites, which intrude the rocks of the Aravalli system, consisting here chiefly of micaceous thin-bedded quartzites, quartz-mica-schists and mica-sillimanite-schists. The epidiorites, granites and pegmatites of this area are regarded to be post-Aravalli and pre-Delhi in age, and none of them is found to penetrate the syenites. Pascoe (1950, p. 266) says that it is not clear whether the syenites should be regarded as a late igneous phase of the Aravalli period (Dharwar) or as an early intrusive of the Purana era and that although the Kishangarh syenites have resemblances to the Charnockite suite, they appear to have still more in common with the Sivamalai elaeolite-syenite of Coimbatore in Madras, the chemical analysis of which agrees very closely with that of the normal Kishangarh rock. In this connection, it may be noted that the recent chemical analyses of the biotite-nepheline-syenite and hornblende-nepheline-syenodiorite of the Sivamalai hills published by Subramaniam (1949, pp. 86-87) do not show such a close resemblance to the Kishangarh nepheline syenite as does that of Walker, referred to by Pascoe (1950, p. 133).

According to Niyogi (1952, pp. 433-34), who has recently made a study of the structure and tectonics of the alkaline rocks of Kishangarh, these rocks, though intruding into the Aravalli rocks, are found to be localised near the junction of the Aravallis and Delhis. The latter rocks are regarded to be thrust against the Aravallis and there is an alignment of several small sills of nepheline-syenite along the Delhi-Aravalli junction. Niyogi therefore, concludes that the nepheline syenites of this area are post-Delhi in age. Thus, it appears that the alkaline rocks of Kishangarh may be correlated with the soda-syenites associated with picrites, pyroxenites, gabbros, etc., which have been described from Sirohi state by Coulson (1933, pp. 87-91), who regards them as post-Delhi and post-Erinpura-granite, but pre-Malani, in age.

IV. POST-DELHI IGNEOUS ROCKS

(i) The Post-Delhi (Pre-Erinpura-granite) and Delhi Basic Rocks

In Alwar state, where these rocks are confined to the Alwar series, Heron (1917, pp. 90-92) had called these rocks as 'amphibolites', but later on, in Western Jaipur, he termed them as 'epidiorites', following the recommendations of the Committee on British Petrographic Nomenclature (Min. Mag., Vol. 19, p. 138, 1921). In western Jaipur, the epidiorites invade the Ajabgarh series as well. According to Heron (1922, pp. 377-78), "their laminae along the bedding planes of quartzite are so straight and regular, so numerous and so thin, that one is inclined to believe them to be lines of metamorphosed volcanic dust, e.g., augitic tuff. The supposition that some of them are altered tuffs or contemporaneous flows does not, of course, negative the proofs that the majority are intrusive". In these rocks which are regarded to have been derived from diorites or dolerites, the conversion of pyroxene into hornblende seems to

have in all cases been complete. According to Heron (Pascoe, 1950, p. 394), the strange phenomenon, that while the neighbouring Erinpura granite is typically foliated, the epidiorites are seldom schistose, shows that the metamorphosing forces of pressure and high temperature, that caused shearing and schistosity in the more yielding rocks, had a different effect upon tougher types like dolerite or diorite, where the result was granulitisation and crystallisation.

Again, in Sirohi state, Coulson (1933, p. 45) has found amphibolitic rocks (amphibolites, hornblende-schists, actinolite-schists, tremolite-epidote-diallage rocks, etc.) very intimately associated with the schists and calcic rocks of the Ajabgarh and they have been subjected to the same folding movements and processes of metamorphism as the latter rocks. There is however, no evidence of the traps being laid down as part of the normal sequence of the Ajabgarh rocks, but intercalated sheets of basic rocks, suspected of being sill-like in nature, are common. Coulson, therefore, suggests that there is not much actual difference between the age of these sills and of the rocks into which they are intruded, while some of the former may be contemporaneous lavas.

Sharma and Nandy (1936, p. 376) have classified the basic intrusives of Danta state into the following three types, based on their structural and mineralogical characters and have suggested that they may represent the three basic phases of igneous activity in this area, during the post-Aravalli period :

3. Younger intrusives (Post-Erinpura-granite).	Olivine-dolerite and olivine-basalt.
2. Older intrusives (Post-Granitoid-gneiss but pre-Erinpura-granite).	Meta-gabbro and meta-dolerite.
1. Oldest intrusives (Post-Aravalli but pre-Granitoid-gneiss).	Epidiorite, pyroxene-granulite, and hornblende-schist.

Recently, Merh (1951, p. 123), has surveyed the Ambamata area of Danta state and he regards the epidiorites, amphibolites and pyroxene-granulites as post-Delhi but pre-Erinpura-granite in age, and the altered coarse-grained dolerites, as post-Erinpura-granite. The difference between the intrpretation of the ages of the former types by Merh and myself lies in the fact that the former author (Merh, 1950, p. 60) has correlated the Danta marble with the Ajabgarh according to Heron's views, whereas, I regard it as Aravallis for reasons explained earlier in this address.

Discussing the age of the meta-gabbro of Danta state, which I regard as pre-Delhi, Heron and Ghosh (1938, p. 400) agree that it is older than

the Erinpura granite but they suggest that it belongs to the epidiorite suite (post-Delhi, according to them)and has escaped greater metamosphism owing to its large size and coarseness of grain. I, however, regard the epidiorite, pyroxene-granulite and hornblende-schist, as an earlier phase of igneous activity—post-Aravalli but pre-Granitoid-gneiss. This difference arises out of the fact that the post-Aravalli Granitoid-gneisses have been mapped in this area as Erinpura granite by Heron and Ghosh.

Certain gabbros, dolerites and granulites, which are few in number and local in development, are found in Sirohi, Palanpur and Danta states. According to Heron and Ghosh (1938, p. 401), "they are veined by the latest fine-grained dolerite and basalt and also by a red pegmatite which may be a derivative of the Jalor granite of Malani age. But, as A. L. Coulson (1933, pp. 127-28) states that the Malani granite (i.e., Idar granite of his nomenclature) is conspicuously free from pegmatite except in the extreme form of quartz veins, and as the Erinpura granite does give rise to red pegmatite, it is not certain that they are pre-Malani in age". It thus seems that these rocks are pre-Erinpura granite and post-Delhi or Delhi, corresponding to my division of meta-gabbro and meta-dolerite.

The order of basic igneous rock types as given above, is the one which is naturally expected in a metamorphic region, the older basic intrusives being more metamorphosed than the younger ones. A similar order based on the degree of metatmorphism of the basic intrusive rocks is being established in the Dhanbad, Gomoh and Kodarma areas of Bihar by the members of staff of the Geology Department, Indian School of Mines and Applied Geology (Sharma, 1940, pp. 137-38; Sharma and Agrawal, 1950a, p. 11; Subrahmanyam, 1950, p. 221 and Sadashivaiah, 1952, p. 105).

Post-Delhi ultrabasic rocks are represented (Pascoe, 1950, p. 386) by talc-schists and chlorite-schists in Beawar and unfoliated talc-limonite-serpentine rock near Ajmer. Recently, Bose (1951) who has carried out field work in the emerald-bearing area of Rajgarh in Ajmer, has suggested that the talc-schists and chlorite-schists are Aravallis. If this be so, the ultra-baic rocks of these areas can be correlated with those of Dungarpur, Mewar, and Idar which at present are believed to be pre-Delhi in age.

(ii) The Post-Delhi Erinpura Granite

La Touche (1902, p. 18) describes the typical Erinpura granite as an exceedingly coarse-grained rock which can be easily recognised by the rounded hummocky knolls into which it has weathered. It is intrusive into the Delhi system but is foliated near its margins. Near the junction with the schists, it is foliated along lines parallel to the junction and the included masses of the schists have been rolled out into lenticular patches and the large felspars are drawn into lenticular 'eyes', surrounded by films of mica and the rock has the appearance of a true gneiss.

According to Pascoe (1950, p. 415), Heron has recognised on the Marwar-Mewar frontier, two types of Erinpura intrusions: (1) :sheet

complex', consisting of innumerable parallel sheets of aplite sheared and imperfectly crystallised pegmatite and granite, the last being both coarse and fine, both porphyritic and even-grained and both foliated and homogeneous; and (2) 'massive stocks' which consist of the normal type granite. Heron regards the sheet intrusions to be earlier but still post-Delhi in age.

I have shown earlier in this address that the sheet granites and the accompanying pegmatites and aplites are more likely to be regarded as acid intrusions of post-Aravalli and pre-Delhi age rather than those of post-Delhi. It, therefore, appears that at least in Danta and adjoining parts of Sirohi and Mewar, the areas mapped as Erinpura granite include also some post-Aravalli (pre-Delhi) granites and the associated pegmatites and aplites.

Further, it is quite possible that some of the masses of intrusions mapped as Erinpura granite may be different types of Malani granite (Jalor, Siwana and Idar types of Lower Vindhyan age), or conversely, some of the latter types of granites may be of Erinpura type. To illustrate the confusion which at present exists in these granites, it may be mentioned that Middlemiss (1921, p. 129) had correlated his Idar granite to the Jalor-Siwana granite of La Touche. Coulson (1733, p. 104) found many outcrops of similar granites in Sirohi and called them also Idar granite; but later on, Heron and Ghosh (1938, p. 385) came to the conclusion that the Idar granite of Idar proper is not the Jalor-Siwana granite but is Erinpura granite. This necessitates inventing of a new name now for the 'Idar granite' of Sirohi state, if the latter is still confirmed to be of Malani age. In this connection it is interesting to note that Hacket (Coulson, 1933, p. 104) had mapped the granite occurring with the rhyolites near Ban in Sirohi state as Erinpura granite. Thus, it seems to me that the granite areas of Sirohi, Danta, Idar and Mewar require a detailed field and laboratory study to delineate the boundaries of the three different granites—pre-Delhi, post-Delhi and Lower Vindhyan.

(iii) The Post-Delhi Erinpura Pegmatites

It will be clear from the preceding survey of the correlations of the various granites of Rajasthan that we are likely to be left with only three granites in this region—the post-Aravalli, the post-Delhi and the Lower Vindhyan granites. Now the question arises as to which of these granites, the mica pegmatites of Rajasthan are associated with. When we consider the other two main mica belts of India, i.e., the mica fields of Bihar and Madras, we find that in both the regions, the mica pegmatites are regarded to be genetically connected with the post-Dharwar but pre-Cuddaph granites—the Bengal Gneiss of Bihar and the Peninsular Gneiss of Madras. We, therefore, naturally expect that in Rajasthan too, the mica-bearing pegmatites may be genetically connected with the post-Dharwar (post-Aravalli and pre-Delhi) granite intrusions. In the geo-

logical map of the portions of Ajmer-Merwara, Jaipur, Kishangarh, Tonk and Udaipur states of Rajasthan, accompanying the paper on the "Minerals of the Rajputana Pegmatites", Crookshank (1948) shows most of the mica mines to be located in the region occupied by the rocks of the Aravalli system or by the Bundelkhand Gneiss. Only a few mica mines which are situated along a belt running north-east—south-west, east of Beawar in Ajmer-Merwara, occur in the rocks of the Delhi system. It is noteworthy that this particular belt of mica mines is just to the east of an elongated belt of Banded Gneissic Complex, about forty miles long, and runs more or less parallel to the junction of this Complex with the rocks of the Delhi system. Further, there is no exposure of Erinpura granite in the vicinity of this mica mines belt. Excepting this belt, it would thus appear that the source of many other pegmatites both in the Aravalli and in the Bundelkhand Gneiss might as well be the post-Aravalli granite. Crookshank (1948, p. 109) is also of the opinion that the source of the pegmatitic material both in the Aravallis and in the Gneissic Complex is the granite, which reaches its maximum development along the axis of the Aravallis. He says: "Heron and Gupta both regard the period of formation of the pegmatites as post-Delhi. This is certainly true of the pegmatites intruded into the Delhis in Bharatpur and south of Delhi. The pegmatites in Mewar, Ajmer-Merwara and Jaipur often show more signs of foliation than those of Bharatpur and Delhi. They may in some cases be older".

There is no doubt that some of the mica pegmatites of Rajasthan are genetically connected with the Erinpura granite. For, Holmes (1949, pp. 293 and 296) has found the age of uraninite from Bisundni pegmatite in Ajmer-Merwara to be 735$\pm$5 million years and of monazite from Soniana pegmatite in Mewar to lie between the limits of 700 and 865 million years. The age of the uraninite from the pegmatites near Singar in Gaya district (Bihar) has been determined to be 955$\pm$40 million years (Holmes, 1949, p. 298, foot-note); but the corrected age of the monazite from Gaya district had been found earlier by T. C. Sarkar (1941, p. 247) to be only 875 million years and recently by P. B. Sarkar (1952, p. 392) to be only 803 million years using Holmes and Lawson's modified formula. So far as the Bisundni pegmatite of Ajmer is concerned, it is evidently younger than the post-Dome-Gneiss (post-Aravalli) Singar pegmatite of Bihar, but the Soniana pegmatite of Mewar may as well be post-Aravalli and pre-Delhi in age, for, its mean age agrees with that of Gaya pegmatite from Bihar.

Apart from the age of the mica pegmatites, there are problems connected with the paragenesis of their minerals. Crookshank (1948, p. 179) who has described in detail the minerals of the Rajasthan pegmatites and their mutual relations, is of opinion that there were two phases in the development of the Rajasthan pegmatites : the potassic and sodic. In the

first phase, quartz and microcline were intruded and in the second, which doubtless followed rapidly the first, a much finer intergrowth of quartz and albite with a little microcline. Further, he thinks that large beryl and microcline crystals were porphyritic crystals formed in deep-seated magma and carried into their present position by a magma composed mainly of silica and water, and that the small crystals of these minerals associated with a relatively fine-grained quartz-albite intergrowth, may have grown *in situ* from a cooling magma. It is inconceivable, how beryl crystals (sp. gr., 2.68—2.72 for Rajasthan specimens), which are sometimes intergrown with tantalite-columbite (sp. gr., 5.43—6.65 for Rajasthan specimens) and which are, though rarely, about 20 ft. long and 20 tons in weight, were carried upwards in a melt of silica and water and supported while the latter crystallised. Moveover, it is believed by many workers that the pegmatite magma works its way through the openings, even of capillary size, and the pinching and swelling out of many pegmatites, both laterally and vertically, supports the view that most of the valuable pegmatites do not simply fill up the pre-existing fissures, some of which, in case of Rajasthan pegmatites, are to be postulated to be open and of such dimensions as to allow huge crystals of beyl and microcline to pass through.

(iv) The Post-Delhi Quartz-Felspar Porphyries

Quartz-felspar porphyries of ages other than Malani have been recorded only from Idar and Danta states. In Idar state, Middlemiss (1921, pp. 128-29) had regarded these porphyries as the hypabyssal equivalents of the Malani rhyolites which they resemble considerably, the only difference being the frequent presence of microcline among the phenocrysts and the predominance of biotite over hornblende in the porphyries. He regarded these rocks as a petrological link between granites of the Idar, Siwana and Jalor types and the bedded Malani rhyolite flows. As mentioned earlier, Heron and Ghosh (1938, pp. 385-87) now regard the 'Idar granite' of Idar state not as Jalor and Siwana type but as 'Erinpura granite', and the presence of quartz porphyries and granite porphyries of the Erinpura suite as a unique feature of Idar state only. According to them, we have in Idar, "preserved a portion of the crust not deeply underlying the ancient surface at the time the Erinpura granite was intruded, in which they solidified under hypabyssal conditions. Nowhere else do such non-plutonic modifications of the Erinpura granite occur and effusive representatives are completely unknown". On the other hand, in Sirohi state, Coulson (1933, pp. 115-127), has described quartz porphyries, quartz-felspar porphyries, felspar porphyries and granite porphyries as the hypabyssal equivalents of his 'Idar granite' of Sirohi state, which is still regarded by Heron and Ghosh as equivalent to Jalor-Siwana granite of Malani age.

In Danta state, lying in between Idar and Sirohi states, Sharma

(1931, p. 22) had described a schistose quartz porphyry from Ambamata area, and had traced a gradation from a white quartz-porphyry through a schistose quartz-porphyry to an almost sericite-muscovite-biotite schist, all the types being characterised by the constant presence of blue quartz. Heron and Ghosh (1938, pp. 377-78) in their resurvey of Danta state say that they are difficult rocks to name and after describing the macroscopic and microscopic characters of some of these rocks, they come to the conclusion that "the balance of probability is that these rocks are arkose, but with the possibility that they might be porphyries. Against this is the fact that the porphyries have never been found elsewhere in Delhis, and they are much too lower down in the Delhi sequence to be the effusives of Erinpura granite which have nowhere been found". In this connection, it may be mentioned that Sharma had regarded this rock as post-Aravalli and pre-Delhi in age and not post-Delhi. Merh (1950, pp. 60-61) has described the schistose quartz and felspar porphyries of the area north of Ambamata, and has found them merging into the granite-gneiss towards south, the latter rock having been regarded by Heron, Ghosh and Merh to be post-Delhi, but by Sharma, as post-Aravalli and pre-Delhi, for reasons given earlier in this address.

Thus, we find that in Rajasthan, in the contiguous states of Idar, Danta and Sirohi, we have quartz and felspar porphyries, which are, in the present state of our knowledge, regarded as belonging to three different ages: Erinpura (post-Delhi), post-Aravalli (pre-Delhi) and post-Erinpura-granite (Malani) respectively. A detailed study of these rock types along with the granites of this region is likely to solve the problem of correlating these porphyry rocks.

(v) The Post-Erinpura-granite (pre-Malani) Basic Rocks

These rocks have been described from Sirohi, Danta and Palanpur states only. In Sirohi, Coulson (1933, pp. 79-109) has described the olivine-, hypersthene-, and biotite-dolerites and olivine-, augite-, and hornblende-basalts. Accordng to him, the usual hypabyssal forms are best described merely as altered basalts or altered dolerites; or, where metamorphosing agencies have been more severe, epidiorites. The plutonic forms, gabbros, picrites and sodalite-syenites, have been noted in three localities only in this state. Regarding the antiquity of the basalts and dolerites, Coulson (1933, p. 95) says: "one can only be amazed that time has treated the majority of these rocks so lightly". In the extreme south of Sirohi state and extending into Palanpur, he (1933, pp. 142-45) has described another set of dolerite dykes which he regards to be tectonically related to and not much younger than the Malani suite. He calls them 'albitised basalts and dolerites' although Borickys' microchemical test, contrary to what was expected, did not show albitisation. It is also interesting to note that specimens of these post-Malani basic rocks consist of laths of felspar and some iron ore. The ferro-magnesian mineral in one

case was found to be biotite and in another, secondary hornblende, and in the third, secondary chlorite. None of the specimens contain pyroxene. Secondary calcite and epidote are also common.

Regarding the age of the pre-Malani hypabyssal and plutonic rocks of Sirohi state, Pascoe (1950, p. 479) writes, that "it must be remembered that the Malani lavas probably belong, not to the lowest, but to the lowest but-one stage of the Lower Vindhyan; that being so, it is possible that the basic intrusions, now to be considered were coeval with the earliest Vindhyan sedimentation and therefore are not pre-Vindhyan in age". Even if we thus bring the two suites of basic rocks nearer to be Lower Vindhyan in age, the fact becomes still more remarkable in that the slightly older suite is fresh whereas the younger one is altered.

Olivine-bearing dolerites and basalts, as well as, altered varieties of basalt in which augite and olivine have been altered completely into magnetite and replaced by calcite, have been described from Danta state by Sharma and Nandy (1936, pp. 371-75) who have regarded these rocks to be post-Erinpura-granite in age, the Malani series of acid rocks being not found in this area to help further correlation.

Heron and Ghosh (1938, pp. 402-3) have described rocks similar to those of Sirohi in Palanpur and Danta states, and they put the oligoclase-dolerite dykes (corresponding to 'albitised basalts' of Coulson) as pre-Malani series and the olivine-dolerite and basalt dykes as post-Malani, a conclusion which is at variance with that of Coulson who regards the latter rocks of Sirohi as earlier than the albitised basalts. The view of Heron and Ghosh seems to be more correct as it follows the natural deduction that older basic rocks show more evidence of metamorphism or metasomatism than the younger ones.

The remarkably fresh olivine-bearing rocks of other regions of Peninsular India are regarded as post-Cuddapah and the bulk of basic dykes may have been formed during the latter half of the Cuddapah period, the intrusion having probably spread over an appreciable lapse of time. These ultrabasic and basic rocks are cited as good examples of the notable absence of widespread disturbance in the southern half of the Indian Peninsula since Cuddapah times (Pascoe, 1950, pp. 470 and 473). They are also regarded as the youngest igneous rocks (except the Deccan Trap) of these regions. Similar rocks in Rajasthan are also the youngest igneous rocks (except the Deccan Trap) in that region, but they are regarded as Lower Vindhyan (post-Malani) due to their cutting the Lower Vindhyan Malani series of acid intrusives and extrusives. Whether some of the basic rocks of the Cuddapah region can be assigned to this age is for the future workers to decide. In any case, post-Malani basic rocks of Rajasthan as well as the Malani series of acid rocks, are beyond the perview of the subject of this address as they are not pre-Vindhyans.

V. CHEMICAL ANALYSES OF IGNEOUS ROCKS

Taking into account the vast area of Rajasthan which has been geologically surveyed, it is surprising that there are hardly a dozen chemical analyses of the various igneous rocks of the region available, and they too, are of specimens collected from isolated localities. Hence, no definite correlation can be carried out on the basis of these analyses. Moreover, the value of such random chemical analyses loses its usefulness still further, especially in case of granites, if we are dealing with an area where injection metamorphism and granitisation have been prevalent to a great extent. The value of chemical analyses for the correlation of basic igneous rocks has been discounted for a similar metamorphic terrain in Bihar by Dunn (Percival and Spencer, 1940, p. 364) who in the discussion of the paper on the conglomerates and lavas of Singhbhum, remarks, "there are basic igneous rocks of at least three separate ages. We have found chemical analyses to be quite useless as a basis of correlation—probably, the original source of all these basic igneous rocks right through the Deccan Trap, was the same". Nevertheless, I have thought it worthwhile to piece together all the available chemical analyses and the norms of the igneous rocks of Rajasthan, in this address (see table at the end) to find out whether they can be of any help in the problem of correlation of these rocks.

(i) *Bundelkhand granite*:—Only one chemical analysis of this rock type is available from Rajasthan proper, and that is from Berach in Mewar (Heron, 1936, p. 7). For comparison, an unpublished analysis of the typical Bundelkhand granite from Mahoba in Hamirpur district in U.P. by Misra (personal communication) is also included. It will be seen from the normative composition of the two specimens (Nos. 1 and 2, Table) of Bundelkhand granite, that both the granites resemble the typical Erinpura granite of Abu in containing normative hypersthene and corundum.

(ii) *Erinpura granite*:—Three chemical analyses of Erinpura granite (Nos. 3, 4, and 5, Table) are available, two from Abu and Waloria in Sirohi (Coulson, 1933, p. 59) and one, from Kawa in Idar (Middlemiss, 1921, p. 121). There can be no doubt about the grey Abu granite being of typical Erinpura type, and this is found to be characterised by the presence of hypersthene and corundum in its norm. According to Pascoe (1950, p. 419), the Waloria granite which is foliated has been found to be different from the Abu granite in its more acid composition and predominance of potash felspar, as well as, in its physical appearance and physiographical features and it resembles more the Idar (Malani) granite than the Abu granite. When we compare the normative composition of the red Waloria granite with that of the grey Abu granite, we find here too, that the two do not resemble each other in as much as there is no normative hypersthene in the Waloria granite, though there is normative corundum. In this respect, it does not resemble the younger Idar (Malani) granite either. It is, therefore, suggested here that it may

represent one of the phases of post-Aravalli (pre-Delhi) granite (granite-gneiss) which has been mapped by Sharma (1933, Map) in Danta state, and by Gupta and Mukerjee (1938, Map) further south in Gujrat. Unfortunately, no chemical analysis is available for any granite of this age. In fact, the post-Aravalli (pre-Delhi) granites are given almost a negligible position in the rock formations of Rajasthan and their occurrences are not marked in any of the geological maps of Heron, so far published.

Regarding the Kawa granite from Idar, Middlemiss had regarded it as Malani granite, but it is now regarded as Erinpura granite by Heron and Ghosh. Coulson (1933, p. 108) also had earlier compared the chemical composition of this granite with that of his Idar granite (Malani) of Sirohi, and had regarded the former as more basic than the latter and approaching the Erinpura granite. The normative composition of the Kawa granite, however, shows a strong resemblance of this granite with the Idar (Malani) granites of Sirohi in containing normative diopside and hypersthene.

(iii) *Idar (Malani) granite*:—Only two chemical analyses (Nos. 6, and 7, Table) of this rock type are available—one from Ban and the other, from Mirpur, both in Sirohi (Coulson, 1933, p. 107). These two analyses are similar to those of Erinpura granite. In fact, Coulson has pointed out that the mean of the two analyses of Erinpura granite from Abu and Waloria very closely approximates to the mean of the above two chemical analyses of the Idar (Malani) granites of Sirohi. But when we compare the normative compositions of the two types of granites, we find that there is no similarity between the two types. The Idar granite contains in the norm slightly more of albite and much less of anorthite than the typical Erinpura granite (No. 3, Table). Further, the Idar granite contains normative diopside and hypersthene, whereas, the Erinpura granite contains normative hypersthene and corundum. These differences are noticeable not only in the norms of individual specimens but also in the case of mean analyses of each of the two granite types from Sirohi.

(iv) *Soda-syenites*:—There are only three chemical analyses available (Nos. 8, 9 and 10, Table)—two of the nepheline-syenites from Kishangarh (Heron, 1924, p. 186) and one of the sodalite-syenite from Mundwara in Sirohi (Coulson, 1933, p. 88). The nepheline-syenite of Kishangarh is characterised by the presence of nepheline, corundum and olivine in its norm; the sodalite-syenite of Sirohi differs from this type by having no anorthite and corundum in its norm but diopside and acmite instead.

(v) *Basic rocks*:—Only four chemical analyses (Nos. 11, 12, 13 and 14, Table) are available—one, of pre-Delhi (Aravalli) dolerite from Karju, Mewar (Heron, 1936, p. 54), one of post-Erinpura (pre-Malani) olivine-dolerite from Kawa, Idar (Middlemiss, 1921, p. 133), one of post-Erinpura (pre-Malani) olivine-gabbro from Chandravati, Sirohi (Coulson,

1933, p. 80), and one of post-Malani albitised dolerite from Kapasia, Palanpur (Coulson, 1933, p. 144). It appears from the study of these analyses that the Karju and Kawa dolerites, though regarded as different in age, are very similar and are characterised by the presence of diopside and hypersthene in their norms. The Chandrawati olivine-gabbro differs, however, from the Kawa olivine-dolerite regarded as of the same age, in the larger amount of normative anorthite, less of normative orthoclase, diopside and hypersthene and in the absence of quartz and the presence of olivine in the norm. The much younger post-Malani albitised dolerite is characterised by containing diopside and olivine and no hypersthene in the norm and also by the presence of normative nepheline.

VI. CONCLUSION

I now come to the end of my address in which I have tried to show that there are controversial points about each one of the types of igneous rocks found in Rajasthan, right from the Bundelkhand granites to the post-Malani dolerites. I have drawn the attention of my fellow geologists to the possibility of some of the granites of Rajasthan being post-Aravalli and pre-Delhi in age. This granite, according to the work of the officers of the Geological Survey of India, practically forms a negligible type in Rajasthan, whereas, the equivalent post-Dharwar and pre-Cuddapah granites are so widespread in the rest of Peninsular India. I know how difficult is the problem of correlation of the pre-Cambrian rocks. It is said that one of the famous geologists, who attended the Canadian meeting of the International Geological Congress and heard the other geologists correlating the pre-Cambrians of the widely separated regions of the world, remarked that he was very much interested to hear these wide correlations, as in his own country, they found difficulty in correlating the ancient rocks across two sides of a stream.

Seventy five years ago, Hacket (1877) wrote the first important geological account of the north-eastern Rajasthan. Later on, working in the central and eastern portions of the Aravalli region, the views of Hacket (1881) underwent a radical change about the stratigraphy of this area, the most important one being that the Raialos and Ajabgarhs had come to be regarded as Aravallis and older than the Delhis. Heron began in 1908 the resurvey of Rajasthan to find out the correct interpretation of the sequence of the rock formations, and in his first Memoir on Rajputana, he (Heron, 1917, p. 105) says about Hacket's work: "Had the second paper remained unwritten, the geology of Rajputana would not have fallen into the confusion from which I am now endeavouring to extricate it". Future workers in Rajasthan will probably pass a similar remark about the work of Heron in Mewar, Danta and Idar states, since Heron himself has inverted the succession of rock formations given by Middlemiss (1921) earlier in Idar state. This is especially true when we see the confusion introduced by Heron in the geology of this part of

Rajasthan by considering the biotite-gneisses and calc-gneisses as Delhis instead of Aravallis (Heron, 1936a, p. 70) with the consequent elimination of the post-Aravalli (pre-Delhi) granite types from this area. I have tried to impress in the course of this address, the necessity of a resurvery of the frontier areas of Idar, Danta, Sirohi and Mewar, which will help us in fixing the correct ages of the sedimentary formations of this area, as well as of the various granitic and basic intrusions.

It is gratifying to note that provision has been made in the University of Rajasthan at Udaipur, for post-graduate (Ph.D.) work in Geology, and if the Geological Survey of India do not find this work of correlation of enough significance to get the areas re-surveyed, may I hope that these non-official geologists from the University of Rajasthan will be able to throw some light on these problems.

It has almost become a custom for the Presidents of this Section to speak, at the end of the Presidential address, about the teaching of the subjects of Geology and Geography, or the facilities and prospects available to the Geologists and Geographers in our country. In this connection, I wish to express on behalf of the Members of this Section, thanks to Dr. M. S. Krishnan, our present Director of the Geological Survey of India, who took the lead, about ten months ago, in this direction and proposed to the Mining, Geological and Mettallurgical Institute of India, to hold a Symposium on "Training for the Mineral Industry". This Symposium has already been held in October, 1952, under the auspices of that Institute, and many of our Geologists, Mining Engineers and Metallurgists have taken part in it. In order to invite more specific comments from the Members of this Section, a similar Discussion on "Training and Proper Utilisation of Personnel in Geology, Geography, Mining, Engineering and Metallurgy" is being held here under the joint auspices of the Sections of Geology and Geography and Engineering and Metallurgy. I am sure something tangible will come out of this Discussion to improve the lot of Geologists and Geographers of our country.

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TABLE SHOWING

THE AVAILABLE CHEMICAL ANALYSES AND THE CALCULATED NORMS OF THE IGNEOUS ROCKS OF RAJASTHAN.

	Granite (Bundelkhand)		Granite (Erinpura).			Granite (Malni).		Soda syenites.			Basic rocks.			
	A. CHEMICAL ANALYSES													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
SiO_2	65.90	72.14	71.48	79.06	66.04	75.46	74.64	55.32	54.52	49.88	50.65	50.23	47.02	54.00
Al_2O_3	16.63	13.64	13.35	11.34	14.77	11.11	12.06	23.78	24.32	17.95	14.38	16.51	20.24	16.37
Cr_2O_3	..	..	..	..	..	..	..	..	..	..	..	0.01	..	..
Fe_2O_3	1.00	0.63	0.06	0.65	1.18	0.11	0.07	4.73	6.62	2.42	1.80	3.83	1.25	1.67
FeO	4.11	2.15	3.83	0.21	4.41	2.24	1.90	..	..	5.33	8.05	8.26	6.34	6.23
MnO	..	0.13	0.09	trace	0.11	0.09	0.05	..	..	0.24	0.15	0.14	0.12	0.10
MgO	1.70	0.19	0.33	..	0.98	0.18	0.07	1.07	0.43	2.37	7.65	5.48	9.56	1.58
CaO	1.40	2.10	1.40	0.28	2.95	1.16	1.12	1.18	1.71	4.14	10.10	9.53	10.54	5.18
BaO	..	..	..	..	0.02	..	..	..	..	..	..	0.02	..	..
Na_2O	2.70	3.06	2.73	2.44	2.56	2.75	3.38	8.46	10.62	8.47	1.70	2.07	2.32	4.51
K_2O	4.38	5.04	5.43	5.89	5.25	5.64	5.60	4.50	1.60	4.55	1.05	1.04	0.47	4.20
$H_2O(+)$	1.55	0.20	0.57	0.32	0.71	0.51	0.78	..	..	0.73	3.00	0.63	1.05	2.51
$H_2O(-)$	0.25	0.34	0.22	0.33	0.21	0.28	0.20	..	..	0.07	0.25	0.08	0.11	0.06
CO_2	..	..	..	..	..	..	..	..	..	..	..	..	0.73	2.81
TiO_2	0.15	0.27	0.59	trace	0.69	0.52	0.40	..	..	2.54	1.25	1.41	0.36	0.82
P_2O_5	0.10	0.37	0.07	..	..	..	0.05	..	..	1.24	0.09	0.31	..	0.23
Cl_2	..	..	..	..	..	..	..	0.64	0.99	..	..	..	..	..
SO_3	..	..	..	..	..	..	..	..	..	..	..	0.23	..	..
ZrO_2	..	..	..	..	0.03	..	..	..	..	..	..	..	..	..
Total:	99.87	100.26	100.15	100.52	99.91	100.05	100.32	99.68	100.81	99.93	100.12	99.78	100.11	100.27

THE AVAILABLE CHEMICAL ANALYSES AND THE CALCULATED NORMS OF THE IGNEOUS ROCKS OF RAJASTHAN.

	Granite (Bundelkhand)		Granite (Erinpura).			Granite		Soda syenites.			Basic rocks.			
	A. NORMS													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Quartz.	25.02	30.00	29.28	41.76	20.88	34.38	30.60	..	..	..	3.18	4.44		
Orthoclase	26.13	29.47	31.69	35.03	31.14	33.36	33.36	26.69	9.45	27.24	6.67	6.12	2.78	25.02
Albite	23.06	26.20	23.06	20.44	21.48	23.58	28.82	39.82	52.40	16.24	14.15	17.82	19.39	36.15
Anorthite	6.12	7.78	6.12	1.39	13.34	1.11	1.11	5.84	8.34	..	28.36	32.53	43.37	11.95
Nepheline	..	..	..	..	..	..	..	17.[illegible]2	20.16	27.26	..	..	..	1.14
Corundun	5.10	0.20	0.82	0.41	..	..	..	2.75	1.43	..	..	..	..	..
Acmite	..	..	..	..	..	..	..	..	..	4.62	..	..	..	..
Diopside	..	..	..	..	1.18	4.12	3.19	..	..	10.55	16.94	10.91	7.17	11.11
Hypersthene	10.67	3.54	6.74	..	7.84	1.65	1.29	..	..	..	22.35	18.12	3.12	..
Olivine	..	..	..	..	..	..	..	1.96	0.84	4.48	..	..	19.70	5.21
Magnetite	1.39	0.93	0.23	0.70	1.86	0.23	0.23	..	..	..	2.55	5.57	1.86	2.55
Hematite	..	..	..	0.16	..	..	..	4.64	6.56	1.16	..	..	..	..
Ilmenito	0.30	0.61	1.22	..	1.37	0.91	0.76	..	..	4.86	2.43	2.74	0.76	1.52
Chromite	..	..	..	..	..	..	..	..	..	..	..	0.22	..	..
Apatite	0.34	1.01	0.34	..	..	..	0.34	..	..	2.69	0.34	0.67	..	0.34
SrO_2	..	..	..	..	0.03	..	..	..	..	..	..	..	..	..
BaO	..	..	..	..	0.02	..	..	..	..	..	..	0.02	..	..
$H_2O\pm$	1.80	0.54	0.79	0.65	0.92	0.79	0.98	..	..	0.80	3.25	0.71	1.16	2.57
CO_2	..	..	..	..	..	..	..	..	..	..	..	..	0.73	2.81
Cl_2	..	..	..	..	..	..	..	0.64	0.99	..	..	..	..	..
SO_3	..	..	..	..	..	..	..	..	..	..	..	0.23	..	..
TOTAL:—	99.93	100.28	100.29	100.54	100.06	100.13	100.68	99.66	100.17	99.90	100.22	100.10	100.04	100.37

1.—Bundelkhand Gneiss, Berach (Mewar), analysed by W. H. Herdsman.
2.—Bundelkhand Granite (pink), Mahoba (U. P.), analysed by R. C. Misra.
3.—Erinpura Granite (grey), Mt. Abu (Sirohi), analysed by F. Raoult.
4.—Erinpura Granite (red), Waloria (Sirohi), analysed by F. Raoult.
5.—Erinpura (? Idar) Granite (hornblende variety), Kawa (Idar), Analysed by W. A. K. Christie.
6.—Idar (Malani) Granite, Ban (Sirohi), analysed by F. Raoult.
7.—Idar (Malani) Granite, Mirpur (Sirohi), analysed by F. Raoult.
8.—Nepheline Syenite (normal), Kishangarh, analysed by B. C. Gupta.
9.—Nepheline Syenite (dark, banded), Kishangarh, analysed by B. C. Gupta.
10.—Sodalite Syenite, Mundwara (Sirohi), analysed by F. Raoult.
11.—Dolerite (Pre-Delhi), Karju (Mewar), analysed by W. H. Herdman.
12.—Olivine Dolerite (Post-Erinpura), Kawa (Idar), analysed by W. A. K. Christie.
13.—Olivine Gabbro (Post-Erinpura), Chandrawati (Sirohi), analysed by F. Raoult.
14.—Albitised Dolerite (Post-Malani), Kapasia (Palanpur), analysed by F. Raoult.

40th INDIAN SCIENCE CONGRESS, LUCKNOW, 1953

SECTION OF BOTANY

PRESIDENT: R. K. SAKSENA, DR. ÈS-SC. (PARIS), F.N.I.

Presidential Address

SOME ASPECTS OF PHYSIOLOGY AND CYTOLOGY OF PYTHIACEAE

I have much pleasure in thanking the Indian Science Congress Association for inviting me to preside over the deliberations of the Botany Section this year and giving me an opportunity of addressing you. In choosing a subject for a presidential address it is customary and proper to give preference to one in which the speaker has been specially interested. It is this which has made me choose as my subject the physiology and cytology of the Pythiaceae. I am fully aware of my limitations, which may not enable me to give a picture complete in detail, yet I shall endeavour to present some of the important aspects.

FAMILY PYTHIACEAE

The family Pythiaceae includes several genera, the well recognized being *Pythium*, *Phytophthora*, *Pythiogeton*, *Trachysphaera* and *Diasporangium*.

The genus *Pythium* was created by Pringsheim in 1858, and was placed in the family Saprolegniaceae. Later, Cornu (1872) and Berlese and de Toni (1888) also agreed with Pringsheim in assigning these genera a position in the same family. In 1881 de Bary published many articles dealing with several genera including *Pythium* and *Phytophthora*, which he for the first time placed in the family Peronosporaceae. A few years later, Fischer (1892) published his monograph on the genus *Pythium* creating subgenera *Aphragmium*, *Nematosporangium* and *Sphaerosporangium*. He treated *Pythium* and *Phytophthora* as closely related genera of the Peronosporaceae. Schröter in 1897 elevated the subgenus *Nematosporangium* (including *Aphragmium*) to generic rank, and included this genus and *Pythium* (synonymous with Fischer's subgenus *Sphaerosporangium*) in a newly created family, the Pythiaceae, assigned to the order Saprolegniales and kept *Phytophthora* in the Peronosporaceae. Butler (1907) in his classical monograph on the genus *Pythium* followed Fischer's treatment in retaining the various species within this single genus. He wrote that the family Pythiaceae 'may be joined with the Peronosporaceae to form an order, the Peronosporineae' (Peronosporales). Fitzpatrick (1923) recommended that *Pythium* and *Phytophthora* and other closely related genera be included in the family Pythiaceae, a division of the Peronosporales.

De Bary in 1876 created the genus *Phytophthora* and recognized its affinities with the genus *Pythium*. The controversy whether *Phytophthora* be merged with *Pythium* or the two should remain distinct and separate genera is well known. Butler (1907), Fitzpatrick (1923, 1930), and Middleton (1943) have discussed this problem at great length.

The genus *Pythiogeton* was described by von Minden in 1916 and *Trachysphaera* by Tabor and Bunting in 1923.

Other genera also were added to this family from time to time. Some of which are *Kawakamia* (Miyabe, 1903), *Pythiacystis* (Smith and Smith, 1906), *Pythiomorpha* (Petersen, 1910), *Zoophagus* (Sommerstorff, 1911), *Stigeosporium* (West, 1916-17) and *Blepharospora* (Petri, 1918). Most of these have been invalidated by various investigators (Barrett, 1917; Fawcett, 1920; Leonian, 1925; Smith and Smith, 1925; Buisman, 1927; Fitzpatrick, 1930; Höhnk, 1936; Blackwell, Waterhouse and Thompson, 1941; Wolf and Wolf, 1948; Bessey, 1950).

Of the genera included in the family Pythiaceae, *Pythium* and *Phytophthora* are well known and contain the greater number of species. They are of economic significance from the viewpoint of plant diseases caused by them.

Physiological Studies

Importance

As is well known physiology is the study of life processes of organisms. The study of fungus physiology is important from various points of view.

In the identification and classification of organisms morphological characters are almost exclusively used by the taxonomist. On the other hand mycologists and bacteriologists lay emphasis on the physiological characters in classifying the genus *Fusarium* and bacteria. The work of Leonian(1925, 1927, 1934) has also shown that reliable physiological characters should be combined with the more constant morphological characters for the classification of the genus *Phytophthora*. Therefore, it should be our endeavour to find out such physiological characters as are uniform and of sufficient value to supplement the morphological characters in the taxonomy of fungi.

Some physiological characters such as the antibiotic behaviour may help us to distinguish two near species over which difference of opinion among the systematists may exist, as has been reported by Pinto-Lopes (1948). This behaviour may allow us to distinguish the (—) strain from the (+) strain as is the case in *Mucor racemosus* (Harris, 1948). Certain antibiotics may be used to control plant diseases (Vaughan *et al.*, 1949; Whiffin, 1950).

For the study of life histories and other aspects of fungi it is necessary to maintain them as stable strains in culture. In many cases it has been noted that organisms in culture become sterile or show less sporulation. If we know their nutritional requirements they can be kept as stable strains without losing fertility.

When a mycologist or a plant pathologist comes across any parasite on a host, one of the problems that confront him is to bring the fungus in culture because that is the first step for studying the physiology of the parasite— a study which is essential for an intelligent control of the disease. In this field there are numerous unsolved problems, and one of them is the cultivation of obligate parasites on synthetic media. Efforts in this direction have enabled some workers to grow some of the so-called obligate parasites in artificial culture, e.g., *Dispira cornuta* (Ayers, 1933) and *Urocystis occulata* (Ling, 1940).

Further a knowlege of the environmental factors including temperature, humidity and light on germination, growth and sporulation of parasitic

fungi is of value for the control of diseases. It is the study of these meteorological factors which has enabled forecasting services in some countries to notify in advance outbreaks of diseases to the farmer so that preventive measures may be undertaken before actual attacks.

The study of the physiology of fungi has led to the progress of many industries based on the mycological production of citric acid, gluconic acid, lactic acid, sterols, oxalic acid, etc., and above all the production of antibiotics such as penicillin, streptomycin and aureomycin. Critical studies have led to the selection of high producing variants of organisms responsible for their production, to the formulation of media most suitable for their maximum yields, and also to the discovery of other relevant factors.

No study of physiology is complete without the study of the principles of enzyme action because the life processes of organisms are controlled and directed by the enzyme systems.

It may not be out of place to point out here that up to the eighteenth century mycologists devoted themselves mainly to the collection and description of fungi, and consequently the study of fungus physiology remained neglected. It was the nineteenth century during which this branch received some attention of the investigators, and only the last forty years have shown notable advances in fungus physiology and a realization of its far-reaching importance.

Now I wish to deal with some aspects of the physiology of the family Pythiaceae. Most of the work has so far been only on two genera, viz., *Pythium* and *Phytophthora*.

Nutritional Requirements

Besides an adequate supply of water, carbon occupies an important place in fungal nutrition. It is well known that the greater part of the dry weight of fungal body consists of carbon since the cell wall, protoplasm, enzymes and reserve food materials stored within its body are compounds of carbon. It is also a source of energy for the organism. Fungi vary in response to different carbon compounds employed to fortify synthetic media. Composition of these compounds, their structure and configuration affect their utilization, and these factors may affect differently in different fungi.

In general, fungi, like bacteria, prefer carbohydrates as sources of carbon. A survey of the literature shows that no particular sugar is the best source of carbon and energy for all fungi. Glucose appears to be the most favourite. Volkonsky (1934) reported that raffinose was readily utilized by *Pythium de Baryanum*. According to Saksena (1940) and Saksena and Mehrotra (1949) dextrose, maltose, soluble starch and sucrose were most favourable for the growth of *Pythium* spp. Arabinose, dextrin, galactose, glycogen, inulin, lactose, levulose, mannose, rhamnose and xylose were utilized by some of them, while raffinose was, in general, the least favourable source of carbon. Margolin (1942, cited by Lilly and Barnett, 1951) observed in the case of *Pythium ascophallon* that fructose, glucose, maltose, mannose and sucrose were utilized, while galactose and lactose were poor sources of carbon and dextrin was not utilized.

Edgecombe (1938) demonstrated that for *Phytophthora cactorum* galactose was a poor source of carbon. From the studies made on twenty-one ungi including four *Phytophthora* species, viz., *Phytophthora cactorum*,

P. erythroseptica, *P. fagopyri* and *P. megasperma**, Margolin concluded that out of seven sugars tested by him no sugar supported the maximum amount of growth for all the fungi, but all were able to utilize glucose, although the maximum amount of growth was not always attained in this sugar. The more closely the configuration of another sugar approached that of glucose the more fungi utilized it. With regard to arabinose and xylose he reported that the latter was more utilized than the former by *Phytophthora megasperma*, but for *P. erythroseptica* they were very poor sources of carbon. Dextrin was not utilized by *Phytophthora fagopyri* like *Pythium ascophallon*. Lopatecki (1950) found that the optimum concentrations of glucose and sucrose were 4% for all species of *Phytophthora* studied by him. Mehrotra (1951) reported that dextrose, maltose, soluble starch and sucrose were the carbohydrates best utilized by the ton species of *Phytophthora*. Inulin and lactose proved as mediocre sources, while arabinose, dextrin, galactose, levulose, mannose, raffinose, rhamnose and xylose wore the poorest sources of carbon. The results of this author and that of Margolin in regard to galactose utilization support the observations of Edgecombe (1938). Raffinose has been reported to be utilized slowly by *Phytophthora cactorum*, *P. palmivora* and an isolate of *P. parasitica*, while another isolate of the last named fungus used it rapidly (Volkonsky, 1934).

For a species of *Pythiogeton*, Cantino (1949) reported that cellobiose, fructose, cellulose, glucose, maltose, starch and sucrose supported growth, while lactose was incompletely used and galactose and melibiose were not utilized at all.

Margolin studied also the effects of mixed carbon sources on the amount of growth of *Phytophthora megasperma* and found it to be purely additive. No work of this kind has been done on other members of the Pythiaceae. In certain fungi it has been reported that, when these were supplied with a mixture of carbon sources, their amount of growth was much more than the calculated one (Horr, 1936). This is an aspect worth investigating.

Saksena and Mehrotra(1949) reported that the alcohols, viz., dulcite, erythrite, glycerine, mannite and sorbite, in general, were less favourable (as carbon sources) than the sugars for the sixteen species of *Pythium* tested. Only *Pythium artotrogus*, *P. de Baryanum* var. *pelargoni*, *P. deliense*, *P. epiphanosporon*, *P. leucosticton*, *P. polyandron* and *P. rhizophthoron* grew well in medium containing glycerine, but in the case of *P. de Baryanum* it was not utilized. The last result is contrary to that reported by Volkonsky (1934) who found it supporting growth of the fungus. Most species appear to utilize the corresponding sugars with greater facility than the sugar alcohols. Margolin reported that *Phytophthora erythroseptica* and *P. megasperma* utilized the corresponding sugars, viz., galactose, glucose and mannose with greater facility than the sugar alcohols—galactitol, sorbitol and mannitol. Mehrotra (1951) tested the utility of some alcohols, viz., dulcite, erythrite, glycerine, mannite and sorbite, and found that only glycerine was assimilated most by the ten *Phytophthora* species investigated. With regard to the comparative utility of alcohols and corresponding sugars the results of this author were in general agreement with those of Margolin.

For *Pythiogeton*, Cantino (1949) found mannitol supporting definite growth, but at approximately one tenth of the rate obtained with glucose as a substrate.

* Syn. *Pythiomorpha gonapodyoides*

The glucoside, amygdalin, was reported to be of little use for the species of *Phytophthora* (Mehrotra, 1951).

Of the organic nitrogen compounds tested as sources for carbon, Saksena (1940) found *Pythium* species utilizing alanine, asparagine, aspartic acid, glutamic acid, leucine, and to a less extent glycine. The carbon from acetamide and urea was not assimilated.

The growth supporting value of fats, other lipoid substances, and of many organic acids has not yet been assessed in the case of the members of the family Pythiaceae. Further, the respiratory studies with carbon compounds also remain uninvestigated.

Protoplasm is composed of nitrogenous substances and many of the vitamins and other essential metabolites contain nitrogen which is also a part of chitinous cell walls of many fungi. Therefore, nitrog n like carbon is used by fungi for functional as well as structural purposes. The various studies made so far in regard to nitrogen utilization indicate that fungi may be specific in the nitrogen sources they utilize. In 1938 Leonian and Lilly studied the utilization of amino acids by *Pythium oligandrum* and *P.polymastum*. Saksena (1940), while investigating the nutritional requirements of some species of *Pythium*, reported on the utilization of various nitrogenous compounds as sources of nitrogen. Later, Saksena *et al.* (1952) found that alanine, asparagine, glutamic acid and urea were favourable nitrogen compounds, while nitrate and ammonium nitrogen supported mediocre, and acetamide poor growth of the thirteen *Pythium* species tested. Lilly and Barnett (1951) have listed *Pythium de Baryanum* (also tested by Saksena *et al.*, 1952), *P. intermedium* and *P. irregulare* as fungi utilising nitrate nitrogen. Robbins (1937), who has classified all organisms according to their ability to utilize different sources of nitrogen, has placed Phytophthoras under organisms which are able to utilize organic nitrogen and unable to utilize atmospheric, nitrate or ammonium nitrogen. He has cited the thesis of Kincaid who worked on thirteen species of *Phytophthora* which failed to grow either in nitrate or ammonia as the source of nitrogen in the presence of dextrose as the source of carbon but grew with peptone. But Mehrotra (1949) was able to grow *Phytophthora cactorum* on media containing either nitrate or ammonium nitrogen. Later, the studies undertaken by Mehrotra (1951, 1951a) indicated that ammonium nitrate as the sole source of nitrogen was able to support the growth of ten species of *Phytophthora*. Lopatecki (1950) was also able to grow *Phytophthora* spp. on inorganic sources of nitrogen. He found that the growth of *Phytophthora cactorum* was greater with ammonia than with nitrate, while the latter encouraged better growth of *Phytophthora erythroseptica*, *P. megasperma* and *P. parasitica*. The case of *Phytophthora phaseoli* seems to be an exceptional one since ammonium nitrogen is not only not assimilated but also inhibits the normal growth (Saksena and Bhargava, 1943). Further work on this species could not be pursued as the fungus died. These findings of Saksena and Bhargava (1943) need confirmation and further investigation. Leonian and Lilly (1938) tested the utilization of various amino acids and found that *Phytophthora erythroseptica* could utilize *dl-a*-alanine, *d*-arginine, *l*-aspartic acid, *d*-glutamic acid, glycine, *l*-histidine, *l*-proline and *dl*-serine, while *iso*-leucine, *l*-tryptophane and *dl*-valine were utilized but not so well. They also studied the utilization of various amino acids by two species of *Pythiomorpha* (*Phytophthora*). They are of the opinion that the species of *Phytophthora* and *Pythium* examined by them are capable of synthesizing their own amino acids from ammonium nitrate. These results

have been supported by the investigations of Mehrotra (1951, 1951a) and Saksena *et al.* (1952).

For the species of *Pythiogeton*, Cantino (1949) found that ammonium nitrogen and glutamic acid supported growth, while nitrate nitrogen did not.

Carbon source is one of the factors influencing the assimilability of nitrogen compounds as reported by various workers (Hagem, 1910; Demmler, 1933; Steinberg, 1939). Mehrotra (1949) found that, in general, ammonia was superior to nitrate as a source of nitrogen for *Phytophthora cactorum*, but in media containing sucrose nitrate was much better than ammonia. This aspect of nitrogen assimilation requires further investigation.

Sulphur is a part of protoplasm, and it has been reported that the activity of many enzymes depends upon the sulphydryl or thiol group -SH. Therefore, it is a structural element. No nutritive medium can ever be of any use unless it contains a suitable source of sulphur. Since compounds containing phosphorus have been isolated from fungi phosphorus is also said to be a structural element. Phosphorus compounds play an important role in the functions of chemical transformations and energy transfer. Recently, Saksena *et al.* (1952) have reported that all the eleven species of *Pythium* investigated can utilize sulphur from inorganic and organic sulphur compounds tried. Mehrotra (1951a) found that of the inorganic sulphur compounds tested the ten species of *Phytophthora* were able to utilize sulphur in the form of sulphate, sulphide, bisulphide, sulphite, metabisulphite and thiosulphate. Persulphate was valueless and dithionate was the poorest source of sulphur for the Phytophthoras. Of the organic sulphur compounds tested *l*-cystine and thiourea served as good sources for sulphur, while cystein hydrochloride was valueless. Cantino (1949) found that a *Pythiogeton* species was capable of utilizing sulphate and cystine. Fischer (cited by Lwoff, 1932) classified organisms into two categories, (1) 'Euthiotrophes' which can obtain their sulphur from 'SO_4' ions and (2) 'Parathiotrophes' which cannot utilize 'SO_4' ions. According to this classification the species of *Phytophthora*, *Pythiogeton* and *Pythium* belong to the former group. Mehrotra (1949) found that *Phytophthora cactorum* and *P. parasitica* were able to utilize potassium dihydrogen phosphate, casein and nucleic acid, and that both the species had different degrees of phosphate tolerance.

Growth substances

The importance of growth substances (used in the wider sense) in the metabolism and growth of plants and animals has now been well established. Many fungi can grow on a medium containing some minerals and suitable carbon and nitrogen sources, and out of these they can synthesize the growth substances they require for their normal growth and other vital functions including reproduction. For such species there is no need of an external supply of growth substances. There are other fungi which are unable to grow without an extraneous supply of growth substances, which they are incapable of synthesizing themselves. The third category consists of organisms which grow slowly in the absence of an external supply of growth substances, but more rapidly if these are added to their media. Such organisms are capable of manufacturing their own growth substances, but do so at a suboptimal rate, e.g., *Pythium polycladon* (Robbins and Kavanagh, 1938) and *P. splendens* (Ronsdorf, 1935). In such cases the deficiency of growth substances acts as a limiting factor and their addition results in a marked acceleration of growth. Robbins and Kavanagh (1942) have given an ex-

haustive account of vitamin deficiencies of filamentous fungi including the members of the Pythiaceae. From the list it is clear that a large majority of Pythia are organisms requiring no thiamin from an extraneous source while some of them and almost all the species of *Phytophthora* including two species of *Pythiomorpha* and a species of *Pythiogeton* (Cantino, 1949) are thiamin requiring organisms. Saksena and Verma (1947) reported that *Pythium acanthicum* did require thiamin, and the same was the case with *Pythium complectens*. Besides thiamin and its moieties, substances such as lentil extract, bios from yeast and yeast extract were found to be essential and useful to *Phytophthora* and *Pythium*. Also a few of these, viz., *Pythium indigoferae*, *Phytophthora colocasiae* and probably *Phytophthora terrestria* require more than one growth substance. In some cases it has been found that the concentration of the medium interferes probably with the synthesis of growth substances (Robbins and Kavanagh, 1938, 1938a; Saksena, 1939; and Saksena and Verma, 1947).

Growth substances are generally required in minute doses, but in higher concentrations they usually inhibit growth. Saksena and Verma (1947) reported that in higher doses of some growth substances tried there was a tendency towards retardation of growth in *Pythium* spp. investigated. Leonian and Lilly (1937) tested about one hundred fungi with regard to the effect of β-indolyl acetic acid (hetero-auxin) on their growth and came to the conclusion that the higher concentrations of this substance proved toxic and the lower ones failed to induce any stimulation. Mehrotra (1951b) found that without a single exception the concentrations higher than one part in ten million of the growth substances tried proved inhibitory to the growth of *Phytophthora* spp.

Aeration and continuous light have been reported to increase the amount of thiamin synthesized by *Pythium artotrogus* and *P. leucosticton* (Saksena and Verma, 1947). Further studies in this direction on other members are desirable.

That the reaction of the medium plays no mean part in the synthesis of thiamin, an indispensable growth substance for a large number of fungi, has been reported recently. Lilly and Barnett (1947) found that pH 3.8 or lower inhibited the synthesis of thiamin by *Sordaria fimicola*. No such work appears to have been done on the Pythiaceae.

Leonian (1935, 1936, 1936a) has shown that some substances are produced by corn roots, garden peas, and certain unicellular algae which are of the nature of auxins and are capable of promoting growth and reproduction of *Phytophthora cactorum*, when added to ordinary nutrient media. Later, Leonian and Lilly (1937) demonstrated a similar effect of the extract of garden peas on some other species of *Phytophthora* and fifteen species of *Pythium*. Hawker (1936) reported that the addition of lentil extract induced the formation of oospores in *Phytophthora erythroseptica* and accelerated their production in *Pythium de Baryanum*.

Enzymes

In nature parasitic fungi growing on their hosts, and saprophytes on their substrates derive their food from complex natural substances such as proteins, polysaccharides and lipoids which as such cannot be taken by them. Therefore, these must be converted into simpler compounds soluble in water before they can be of any use to these organisms. This function is performed

by enzymes (known as exoenzymes) secreted by them. After the simpler compounds have entered the cells, synthesis of complex substances takes place with the help of enzymes contained in them and known as endoenzymes.

Brown and his students have now established that in the mechanism of parasitism an important part is played by a cell-wall dissolving enzyme, pectinase, secreted by the hyphae of the parasite. Chona (1932) and Menon (1934) studied the pectinase enzyme secreted by certain fungi including *Phytophthora erythroseptica* and *Pythium de Baryanum*. The studies of Chona (1932), Menon (1934) and Damle (1952, on Pythia) have shown that constituents of the medium for the culture of these fungi have a marked effect on enzyme production, and that the enzyme activity is dependent on pH. A parallelism has also been observed by Damle (1952) between the capacity of the *Pythium* species to produce pectinase enzyme and their ability to parasitise potato and lettuce tissues.

Saksena and Jafri (1950) studied quantitatively the various endo- and exo-enzymes of seven species of the genus *Pythium* and found that amylase, emulsin, invertase, maltase and raffinase were present in greater quantity as endo- than as exo-enzymes, while hemicellulase was much more as an exo- than as an endo-enzyme. Butyrase, catalase, lipase and proteolytic enzymes were also present, the second one as an endo-enzyme only. Laccase, oxidase, rennatase and tyrosinase were absent. Earlier, the quantitative enzyme studies carried out on Phytophthoras by Mehrotra (1949a) had shown that amylase, cellulase, emulsin, hemicellulase, invertase, maltase and raffinase were present both as endo- and exo-enzymes. Butyrase, lipase and lipolytic and proteolytic enzymes were found in small quantities both as exo- and endo- enzymes. Catalase was present in very small quantities only. Laccase, oxidase, rennatase and tyrosinase were found to be absent. A detailed study of the factors governing the production and activity of the above mentioned enzymes is worth attempting.

H-ion Concentration

Besides the various aspects dealt with above, there are other factors also which play no insignificant part in the activities of fungi. The pH of the substrates both in nature and in culture has a definite effect upon the rate and amount of growth and upon many other vital processes such as sporulation, production of enzymes, vitamins and antibiotics. Reinking (1923) found that the two strains of *Phytophthora faberi* on coconut and caco in the Phillipine islands were able to tolerate a wide range of H-ion concentrations, the optimum being pH 7.4 to 7.8. Cooper and Porter (1928) observed that a *Phytophthora* isolate, which caused peony blight, produced numerous oospores at pH 6.6 and 8.4, while at 5.3 there were comparatively few oospores and conidia. The results of Jackson (1940) regarding the effect of pH on the growth of damping-off Pythia showed the absence of growth at pH 2.5 and 3.5, while the maximum occurred at pH 5.5 and 6.5. Girginkoc(1951) reported that beet plants inoculated with *Pythium irregulare* succumbed in large numbers at pH 4.9. The incidence decreased till at pH 7.1 there was no mortality. Saksena (1936) studied the reaction of media on the growth of *Pythium deliense*, and reported that there were two maxima, one at pH 5 and the other at pH 9, with the isoelectric point at pH 7, and that there was no growth at pH 10.6. Mehrotra (1949) also noted two maxima, one on the acidic and the other on the alkaline side, in the case of *Phytophthora cactorum* and *P. parasitica*. Between the two maxima there was an isoelec-

tric point at pH 7. Cantino (1949) found maximum growth of *Pythiogeton* in the neighbourhood of pH 6.5. Growth was negligible at pH 4 or below, and at 7.5 or above. Reference has already been made to the effect of pH on the activity of enzymes.

Temperature and Moisture

Tucker (1931) and Middleton (1943) have summarised the relations between temperature and growth in Phytophthoras and Pythia respectively. Regarding *Pythiogeton* Cantino (1949) reported 29°C and 20°C as the maximum and minimum temperatures for growth. While temperature is the main controlling factor in the geographical distribution of disease, moisture is probably more important in the local fluctuations of disease within a particular climate. The incidence of a number of root diseases caused by species of *Pythium* and *Phytophthora* is increased by a high content of moisture in soil. The growth and sporulation of *Phytophthora infestans* has been reported by Collins (1925) to be correlated with the water content of potato leaves—gre ter susceptibility being associated with higher water content.

Micro Elements

It has now been well established that there are certain micro elements which are essential for normal growth and sporulation of fungi. Very little work of this nature has been done on the members of the Pythiaceae. Robbins and Harvey (1944) have demonstrated that manganese is essential for *Phytophthora megasperma*, and Steinberg (1948) has reported on the importance of calcium in the nutrition of *Pythium irregulare.* Millikan (1938, 1942) in Australia observed a definite improvement in wheat crops attacked by several root infecting pathogens on the addition of zinc sulphate, and Sarojini (1951) reported a distinct fall in *Fusarium* colonization in pot experiments with the addition of zinc nutrient solution. For the literature on the effect of minor elements in the physiology of fungi reference may be made to the review by Perlman (1949).

Cytological Studies

Importance

Since the position which cytology in the present day has come to occupy in the science of Biology, and the history of the development of cytology have been admirably dealt with by my predecessor, Dr. S. Ramanujam (1952), I shall like to make only a few observations on this subject.

Broadly speaking cytology today can be classified into two branches: the nuclear and the cytoplasmic cytology. The use of 'paraffin method' has resulted in the striking discovery of karyokinesis and has rendered great service in the study of the nucleus and in particular of the chromosomes, the forms of which are preserved with a minimum of distortion. For this study the smear technique has also been of considerable help. On the other hand the 'paraffin method' has given only mediocre results as far as the cytoplasm is concerned. During the present century rapid progress has been made in the knowledge of the cytoplasm. Near about 1908 the appearance of ultramicroscope enabled Mayer and Schaeffer (1908) to collect some essential data on the colloidal nature of the cytoplasm of animal cells — data which can be applied to plant cells also. At about the same time the introduction of 'mitochondrial methods' led to the discovery of chondriosomes. A little later, the methodical use of vital dyes enabled workers to

follow the evolution of vacuoles through all stages of cellular development. Finally, other techniques and inventions contributed towards a knowledge of the physical properties of the cytoplasm and of its various morphological elements. The French school, led by Dangeard (P.A.) and Guilliermond, has contributed much to our knowledge of the cytoplasmic inclusions. Their method has been the use of selective vital dyes coupled with fixation procedures.

Since fungi do not contain chlorophyll and many of them can be observed in their own environment and since reproductive bodies of a number of these are sufficiently transparent to permit examination without manipulation, they have lent themselves admirably to the study of cytoplasmic inclusions. On the other hand the small size of nuclei in the lower fungi has not allowed the investigators to study the chromosomes in detail.

Cytological studies help us to distinguish precisely one generation from the other in the life history of an organism. Further, cytogenetical investigations of fungi have also proved to be useful in several ways. On the basis of such studies Pinto-Lopes (1948) has tried to explain the differences of antibiotic power in the different isolations of some species of the Hymenomycetes. Also hybrid strains of yeast have been obtained which show combinations of desirable characters valuable in the fermentation industry (Lindegren and Lindegren, 1946; Winge and Roberts, 1948). The genetical work with species of *Neurospora* has given clues to the path of synthesis of certain amino acids (Bonner, 1946). A study of the inheritance of pathogenicity has made it possible to forecast the origin of new races in nature. Waterhouse (1929) produced two races of *Puccinia graminis tritici* that are new to Australia by crossing race 43 with race 34. By selfing race 34, he (1935) obtained race 11 which was subsequently found in an area where infected barberries are common. Earlier, he (1932) obtained two new races of *Puccinia triticina* by inoculating *Thalictrum*. Flor (1946) studying the mode of inheritance of pathogenicity in linseed rust, *Melampsora lini*, found that in crosses between physiologic races virulence was invariably dominant. From 133 F_2 cultures of hybrids of race 22 with race 24, 64 races were identified of which 62 had not been isolated previously. Genetics of fungi has been reviewed by Lindegren (1948).

I shall now mention in short the work done on the cytology of the members of the Pythiaceae.

Zoospore Formation

Not much cytological work has been done on the zoospore formation in the Pythiaceae. Edson (1915) reported that the zoospore in *Pythium aphanidermatum* was uninucleate with top-shaped nucleus which had a nucleolus at the large end and a blepharoplast at the other. The zoospore of *Phytophthora palmivora*, as figured by Cotner (1930) also contains a single nucleus. Earlier, Allain (1935) found that the nuclei in the mycelium and sporangium normally divided amitotically, while mitosis was observed in the egg.

Oogenesis

Studies on the nuclear behaviour in the species of *Pythium* investigated before 1901 were incomplete. Trow (1901), working on *Pythium ultimum*, published in 1901 the first detailed account of the cytology of sex organs. In the same year Miyake (1901) made observations on the cytology of *Pythium de Baryanum*. In 1915 a cytological account of *Pythium aphanidermatum*

(*Rheosporangium aphanidermatum*), and in 1927 that of *Pythium torulosum* was reported by Edson (1915) and Patterson (1927) respectively. A fifth species, viz., *Pythium deliense*, was investigated by Saksena (1936). Though they report some minor differences yet all of them are unanimously against the earlier belief of a collective nuclear fusion in the oogonium. According to them only one male nucleus, fuses with a single female nucleus, *i.e.*, the mature oospore is uninucleate. What happens in cases where several antheridia are attached to one oogonium has not been worked out. Their opinions in regard to the presence or absence of a coenocentrum differ. This body is prominently mentioned in the literature dealing with other families also. It is not known whether it represents dispersed products of the gametic nuclei, coacervated elements from the oosphere cytoplasm, or merely an artefact due to inadequate fixation and staining. The cytological comparison of the above mentioned species of *Pythium* by Saksena (1936) emphasizes, on the basis of nuclear behaviour and extranuclear structure, the intermediate position of the Pythiaceae between the Saprolegniales and the Peronosporales.

In *Pythium*, Trow (1901), Miyake (1901), Edson (1915), Patterson (1927), Dangeard (1931) and Saksena (1936a) have reported the presence of a conspicuous central body in each nucleus. The controversy is about its nature. Is it a nucleolus (Edson, 1915; Dangeard, 1931; Saksena, 1936a) or a nucleolus plus chromatin (Trow, 1901), or only a mass of chromatin (Miyake, 1901; Patterson, 1927)? With the help of Feulgen reaction Saksena (1936a) has been able to demonstrate that the central body is a nucleolus and is not made of chromatin.

The number of chromosomes in the nucleus is either known imperfectly or not known at all. According to Trow (1901) their number in *Pythium ultimum* is six or more, and according to Saksena (1936) it is four or eight in *P. deliense*, while in other species it is not known.

It has been reported that nuclei in the sexual organs undergo division before fertilization. The significance of this division still remains obscure, and none has been able to find the reduction division in the species so far investigated. Only Edson (1915) reported that the first division of the fusion nucleus appeared to be the reduction division, but he was unable to count the chromosomes definitely.

Centrosomes— one on either pole of the spindle— have been reported in *Pythium torulosum* by Patterson (1927) and in *Pythium deliense* by Saksena (1936a).

Oogenesis in *Phytophthora erythroseptica*, *P. cambivora* and *P. himalayensis* all the three possessing amphigynous antheridia, has been worked out by Murphy (1918), Allain (1935) and Mundkur (1949) respectively, while in *Phytophthora cactorum* (normally having paragynous antheridia) by Blackwell (1934). The oogenesis in these fungi is essentially like that in *Pythium*. Mundkur (1949) has reported several points of difference between his material and several species with paragynous antheridia which throw some light upon the evolution of the amphigyny. Only in *Phytophthora cambivora* coenocentrum has been reported (Allain, 1935). In general the central body in the nucleus has been termed the nucleolus. Meiosis has not yet been demostrated in any species. The number of chromosomes in Phytophthoras still awaits investigation. In this genus also the significance of nuclear division before fertilization is not known. In the heterothallic species of *Phytophthora* it will be worth investigating as to where the segregation of sex takes place.

Chondriosomes

Of the various synonyms occurring in the literature the term 'chondriome' proposed by Meves in 1908 (cited by Guilliermond, 1941) for the entire chondriosomal content of a single cell, is used by most of the French cytologists. Newcomer (1940) retained the term mitochondria coined by Benda in 1897 (cited by Newcomer, 1940) on the grounds of common usage and a certain priority. For a long time chondriosomes (mitochondria) were considered either as artefacts or symbiotic bacteria. Investigations during the present century have added much to our knowledge of their structure, and physical and histochemical characteristics. According to Guilliermond (1941, p.56) the chondriosomes were first observed in animal cells but Newcomer (1940, p. 86) is of the opinion that they were first seen in plant cells and their first adequate description and suggested function resulted from the study of insect cells. In his review he has not quoted any literature in regard to their being observed for the first time in plant cells. The first detailed description of chondriosomes in plant cells was made by Meves (1904) who observed them in the tapetum cells of young anthers of *Nymphaea alba*. The chondriome in fungi was described for the first time in the ascus of *Pustularia vesiculosa* by Guilliermond in 1911. Chondriosomes are made up of lipoprotein complex in which lipoids (phosphoaminolipoids) predominate. It is probable that they are surrounded by an absorbed layer of protein which prevents them from being stained by fat dyes (Bourne, 1942). Ordinary fixatives containing acetic acid or alcohol profoundly alter the chondriosomes. This is the reason why they escaped attention of earlier workers before the introduction of mitochondrial fixatives containing usually strong oxidising agents which presumably convert the unsaturated fatty acids of chondriosomes to hydroxylic acids rendering them chromatic with acid dyes. They may be granular, rod-shaped or filamentous. These elements exist in every plant cell except in bacteria and the Cyanophyceae. Chondriosomes are living permanent elements which maintain their individuality in various phases of the life cycle of an organism and they are never seen to arise *de novo*.

Guilliermond's book, The Cytoplasm of the Plant Cell, and reviews by Newcomer (1940, 1951) give elaborate accounts of chondriosomes. The function of the chondriome in plant cells—more so in fungi— is not known definitely. There are various hypotheses in respect of their role. They have been considered as centres for reduction and oxidation, as sources of proteases and various diastases, as centres of oxidases and vitamins, as chemical catalysts, as centres of secretion, and as playing some role in heredity and in respiration.

The chondriome in *Pythium aphanidermatum* and *P. muscae* was investigated by Edson (1915) and Dangeard (1931) respectively, while in the case of *Phytophthora cambivora* it was worked out by Dufrénoy (1926) and Allain (1935). Saksena (1936), and later Saksena and Bose (1948) investigated the chondriosomes in many species of *Pythium*. Mehrotra (1949) studied these elements in many species of *Phytophthora*. The fixation procedures in all cases were coupled with the use of several vital dyes for examining the fungus material *in vivo*. Their results are summarised below.

All the three forms of chondriosomes, i.e., granular, rod-shaped and filamentous were present in varying proportions. Acetic acid, alcohol, commercial formalin and picric acid had no marked effect on them specially in *Pythium*. They were not destroyed up to a temperature of 55°C. With the Kolatchev's technique the chondriosomes were preserved, vesiculisation

being more marked in hyphae kept in the fixative for 15 days. Janus green Höcht B proved to be least toxic, while Dahlia violet and other vital dyes—specially in higher doses—caused much vesiculisation. They were not seen arising *de novo*. They were observed fragmenting.

It has been reported that in animal cells the composition of mitochondria appears to vary in different tissues under different conditions (Bourne, 1942). This has been the experience also of Saksena (1936) and Saksena and Bose (1948) in the case of *Pythium* spp. where they found that fixatives containing alcohol or acetic acid or both produced no marked effect on the chondriosomes, showing that they differ to some extent in their chemical composition from those found in green plants and some fungi.

Vacuoles

Spallanzani (1776, cited by Zirkle, 1937, p.1) for the first time observed vacuoles in animals, and Meyer in 1835 depicted a vacuole in a mature plant cell. It was de Vries (1877-1886, cited by Zirkle, 1937, p.2.) who brought out the importance of vacuoles in osmotic phenomenon of the cell and showed that a mature plant cell may be compared to a small osmometer. Went (1883, cited by Zirkle, 1937, p.2), a student of de Vries, reached the general conclusion that all plant cells contain vacuoles. For a general survey of the literature reference may be made to the reviews by Zirkle (1937) and Guilliermond (1941).

The vacuolar system of a cell, whether the cell had one or more vacuoles, was called the vacuome by Dangeard. The question of the origin of the vacuoles remained uncertain for a long time, because neither observation of living material nor fixed and stained preparations made it possible, in general, to follow the development of these elements. De Vries (1885) and later, his student Went (1887), held that vacuoles were permanent components of the cell and could not in any case arise *de novo* but were always transmitted by division from cell to cell like nuclei and plastids. Sharply opposed to this view was that of Pfeffer, Nemec and other botanists (cited by Guilliermond, 1941, p. 128). They were of the opinion that vacuoles simply arose *de novo* in the cytoplasm whenever water and certain dissolved substances became abundant enough to form visible droplets. Credit must go to Dangeard (cited by Guilliermond, 1941, p. 129) who initiated researches in a new direction by establishing the fact that the ability to accumulate vital dyes was a general property of vacuoles. From this time onwards rapid progress was made in the study of the origin and evolution of the vacuome. Guilliermond (1941) and his students made notable contributions in this field.

Various functions have been ascribed to vacuoles in plants, but the three most likely ones are the maintenance of osmotic pressure, storage of a large number of metabolic products, and excretion of toxic substances. Recently Bose (1943, 1950) has emphasized that plant vacuoles—specially in fungi—are most probably the store houses of enzymes.

The vacuome in many species of *Pythium* and *Phytophthora* has been studied by Saksena (1936) and Saksena *et al.* (1949) with the help of vital dyes. Their results are summarised below.

It has been found that the acid dyes, in general, do not penetrate the living hyphae. A few are incapable of colouring any component except the cytoplasm. Of the basic dyes neutral red, found to be the least toxic, accumulates only in vacuoles; cresyl blue, nile blue and toluidine blue (2 mg. per cent.)

accumulate in vacuoles but in higher concentrations they colour the cytoplasm and nuclei also. Basic fuchsin, Bismark brown and methylene blue have an affinity for cytoplasm, while Dahlia violet, Janus green Höcht B and methyl violet have an affinity for chondriosomes. Cresyl blue, Janus green Höcht B and methylene blue are reduced to their leucobases when used intravitally. Their leucobases behave like their oxidised forms, but the stable pink derivative of Janus green is unable to enter the living hyphae. Neutral red is of great help in finding out whether the cell is living or dead. It accumulates in vacuoles in the living cell, but on its death it is thrown out of the vacuole and it then stains the dead cytoplasm.

In species of *Pythium* and *Phytophthora* studied, vacuoles at the tips of hyphae are generally small, round or ellipsoidal bodies, and further back, are seen as vacuolar canals which extend long distances inside the hyphae. They are seen arising *de novo* at the extreme tips. Fragmentation of bigger vacuoles into smaller ones is also seen.

Vacuoles in the vegetative mycelium of species of *Phytophthora* are not stained intravitally with neutral red, while in the species of *Pythium* growing on a poor medium they take up the dye. In *Pythium* spp. neutral red accumulates in vacuoles between pH 5.5 and 8.5. Metachromatin and tannins are absent in the vacuoles.

Many investigators who have studied, without the help of vital dyes, the life histories of *Pythium* and *Phytophthora*, have made general observations on vacuoles in their reproductive organs.

Golgi Apparatus

By using methods of silver nitrate impregnation the Italian investigator, Golgi (1898), brought out in the cytoplasm of nerve cells of the barn owl's brain a network of very fine filaments which he called the 'internal reticular apparatus', later known as the Golgi apparatus. In animal cells the tests for it, as summarised by Gatenby and Beams (1950,p. 386) are that (a) it goes black in the formalin silver nitrate and osmic Golgi apparatus methods, (b) except possibly for certain male germ cell dictyosomes it does not stain in neutral red, (c) it passes centripetally and is found below the fat in ultracentrifuged cells, (d) it does not stain in methylene blue and (e) it is not dissolved out of formol fixed material by paraffin imbedding. Attempts to homologize the Golgi apparatus with some constituents of plant cells have not met with success. Some of the important hypotheses are briefly reviewed below.

Having been struck by the resemblance of the young filamentous and reticular vacuoles in embryonic cells to the formation known as the Golgi apparatus in animal cells, Guilliermond at first formulated the hypothesis that the Golgi apparatus might well correspond to the vacuolar system in plant cells. The zoologist Bowen (1928) found in the cells of some higher plants structures which he called 'osmiophilic platelets' and he felt inclined to homologize these with the Golgi apparatus. Gatenby (1928) and his collaborators also were of the same view. Beams and King (1935) claimed to have demonstrated the existence of the 'osmiophilic platelets' of Bowen and Gatenby by subjecting the bean root tips to ultra-centrifuging.

Weier (1932) after studying the Bryophyte plastid concluded that probably plastids in plant cell were homologues of the Golgi apparatus.

During this period Guilliermond and his students continued investigating a vast and varied plant material to find out a homologue of the Golgi apparatus, and in view of new researches Guilliermond (1935) published his revised views on the subject. According to him (Guilliermond 1941, p. 199) "the Golgi apparatus does not exist in plant cells. If we pass in review the various work on cells carried out with the idea of finding a Golgi apparatus, we see that all that has been described as such corresponds either to the vacuolar system or to the chondriome (chondriosomes and plastids)". Further his researches have proved that the so called 'osmiophilic platelets' are nothing but the vesiculated chondriosomes in most cases.

Saksena (1936), using the Golgian technique, arrived at the same conclusion, in the case of some species of *Pythium*, regarding the Golgi apparatus. The work done on the Golgi apparatus in plant cells has been reviewed by Nahm (1940).

Conclusion

In the short time at my disposal I have tried to give an account of some aspects of the physiology and cytology of the Pythiaceae, and at appropriate places have indicated where more work is needed. From what I have said it is apparent that most of the work so far has been on two genera only, viz., *Pythium* and *Phytophthora*. The other genera remain uninvestigated, probably on account of their lesser economic significance. In India fungus physiology and cytology, in general, have so far not received as much attention as they deserve, but I hope that more contributions will be forthcoming.

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40th INDIAN SCIENCE CONGRESS, LUCKNOW, 1953

SECTION OF ZOOLOGY AND ENTOMOLOGY

Presidential Address

President.—N. KESAVA PANIKKAR, M.A., D.Sc., F.A.Sc., F.N.I.

A FEW THOUGHTS ON THE PROGRESS OF ZOOLOGY IN INDIA

I am deeply conscious if the honour which the Science Congress authorities have done me in electing me as President of the Zoology and Entomology Section of the Congress for this year. My contacts with the Congress are somewhat recent and I still remember the intellectual enjoyment of my first participation at this Congress which was at the Silver Jubilee Session celebrated in Calcutta in 1938. It has been a great privilege to extend the friendships and associations with fellow Zoologists from all over the country which this large organization has enabled me during the many subsequent sessions. It is, therefore, no small pleasure for me to be the recipient of your esteem which I value highly.

INTRODUCTION

Sectional Presidents of the Congress usually select for their addresses topics in which they have made contributions to the advancement of knowledge, reviewing the subject from the perspective of their own scientific work. This general practice has, however, been departed from by some of our previous Presidents. In these days of increasing specialization, any subject of restricted interest, as I would have been inclined to select from my own field of study, would probably appeal to only a section of our colleagues assembled here. On the other hand there are certain points in the general progress of our Science which appeared to me as being worthy of examination from the standpoint of its further development for which we all strive. Opportunities when Zoologists of different interests meet and exchange ideas are not frequent in our country of distances; such meetings when they do take place are utilized for the exchange of factual information on problems of investigation. Facts and ideas are essential to the development of any science and it is occasionally useful to examine the conditions under which facts are discovered and ideas developed. It would have struck many of us whether the status of zoological studies in our country at the present time is such as would foster the advancement of our Science in the same manner as creative work in the field of biology is encouraged by such studies elsewhere. In this brief address I wish to place before you a few thoughts on the progress of Zoology in India. It is natural that in presenting these observations, I may have emphasized some of our shortcomings rather than our achievements. It is not my desire to underrate the great efforts which our colleagues throughout the country are making to improve

zoological work in the class room and in the laboratory. There are, however, many difficulties yet to be overcome, while new problems continue to arise retarding the progress of our science. As scientists, we have to face these problems with courage and intellectual honesty and strive for the integrated advancement of zoological sciences. In a country like ours, which is predominantly agricultural, with problems of population, food and public health remaining to be tackled on a scale so vast as never before attempted in any other country, it does not require special mention that the development of higher Zoology in the applied branches has to make major contributions to human welfare. Such progress in the applied field can take place only if our institutions proceed with sound teaching and research in Zoology, developing the Science as a fundamental branch of knowledge.

FACTORS RETARDING PROGRESS

It is also appropriate that an examination of factors retarding our progress is done at Lucknow which is now, thanks to the efforts of Prof. Bahl, probably the most advanced centre of University Teaching of Zoology in India. In his address to the 11th Session of the Science Congress at Bangalore in 1924, Bahl dealt with aspects of zoological work in the country which required new orientation and pointed out the means whereby we could effect substantial changes. The remarks then made by him on many points hold good even to this day in spite of the several steps forward taken by us during the past thirty years. Recently, he has also indicated the need for further reorientation and emphasis on physiological work. Almost all of our 27 Universities in India teach Zoology and most Universities have many institutions preparing candidates for University Degrees with Zoology as principal or as subsidiary subjects. If we are to note the number of Graduates in Zoology coming out every year from our Universities, we should be able to report a very impressive figure, but it is a matter of great disappointment that even though a large number of persons receive zoological training, the number of real Zoologists turned out from the Universities is indeed small. This is something which should set us thinking. Are the large numbers of trained graduates not available to the country because of lack of opportunities? If it is not entirely lack of opportunities, what are the causes for the low output of original observations by the vast majority of our University men, among whom may also be counted many actively connected with intellectual life and teaching? Similarly, although we now encounter in all walks of life persons who have learnt the subject in their Universities, how few of them have kept any interest in our branch of science, which, without much expense or equipment, can provide unrivalled opportunities for pursuit in our country? The conclusion is inescapable that our methods of instruction at the University stage have not been such as to create in most of our men a living interest in the science to be

pursued for its own sake with the same enthusiasm as one may take to certain other branches of knowledge. I am aware that this criticism is not necessarily confined to Zoology but in a large measure can be applied to most other sciences.

ZOOLOGY AND THE COMMON MAN

Lack of popular interest.

Ample evidence exists that interest in animal life was keenly evinced by our people from ancient times but the science of Zoology in its present form is, however, new to our soil and has grown only as a result of British influence beginning from the later part of the last century. The majority of our early professors and specialists were either British Scientists or those trained in British Universities and their pioneer efforts have been the cause of the growth of Zoological Departments all over the country. The subject, on the whole, has remained an intellectual pursuit at the University or the Degree College and it has never diffused from those centres of learning to the Common Man—neither to the educated people of the towns nor to the people of our villages. To most of them the subject is either repugnant as a discipline which requires the handling, dissection and examination of 'low and disrespectable' organisms or at best as a necessary evil in the form of a subject of study for securing a Degree. Unlike many other disciplines, more especially belonging to the humanities, the educated public find it difficult to take interest in zoological topics. The gap between the Zoologist at a centre of learning and the person of general culture is something enormous in the field of general biological knowledge. As a first step in the progress of our Science, I wish to draw attention to the immense task of popularization of our subject that awaits us and to say that diffusion of zoological knowledge to the common man is something which calls for an all-round effort. Let us see how this may be effectively done.

POPULARIZATION

It may be legitimately asked whether such diffusion of knowledge is essential or even desirable. To those brought up in the background of classics and nurtured in humanities, this may even appear as totally unnecessary. While the spectacular achievements of physical sciences and the philosophical basis of mathematics impress them, it is not unusual to find persons of culture totally disinterested in the forms of animal and plant life around them. For these shortcomings in our people, we have also to take part of the blame because we have not taken sufficient pains in putting our knowledge across to the common man and to impress on him the very high cultural background provided by our Science. Intelligent appreciation of nature, based on full knowledge of living forms around us is an objective in which, had we been enthusiastic, we should have had little or no difficulties in enlisting sympathy and active coopera-

tion. Protection of living organisms is a sentiment which runs through centuries among our people. We could create interest in the enjoyment of nature, the preservation of that nature from wanton destruction by ourselves and the part animal life around us plays in the economy of our lives—all leading to a biological outlook based on a fuller knowledge of animals and plants around us. Among the so-called educated persons, how few know the zoological processes involved in people contracting malaria, locusts damaging our crops, parasites causing diseases, fish being cultivated or our lives made uncomfortable by insect intruders.

DEFECTIVE FOUNDATION IN THE SCHOOL

The complete absence of biological outlook among the vast majority of the people is mainly brought about by the neglect of the subject in our schools. The languages, mathematics, history, geography and many other subjects are taught, but when it comes to biology the subject is either omitted or relegated to dry-as-dust descriptions of a few plants and animals. It is often forgotten that to the school-going boy or girl, his or her own body is a matter of considerable interest and factual information of how the body works will always be of absorbing interest. Similarly the general cultural aspect is overlooked that among living organisms can be understood patterns that grow from simple to the more complex and advanced forms of life unfolding the concept of evolution, an impression of which will generally give to the growing mind the broadest outlook in the history and progress of human achievements.

INADEQUATELY EQUIPPED MEDIUM OF INSTRUCTION

Terminology.

In laying the proper foundations of biological teaching in our schools the major difficulty at the present time is the fact that our languages are not adequately equipped to impart instruction in biology. In the vast majority of our schools, the subject is taught in the regional languages, about the advantages of which there is no difference of opinion. Practically no Indian language has a sufficiently developed vocabulary or suitable text-books or general works on the basis of which instruction in Zoology, Physiology and Botany could be given to the pupils. The result of this has been the almost complete neglect of biological sciences at the School, giving no background to boys and girls for a wide concept of living organisms. The preparation of suitable simple books in biology in our prinpal languages of the country should receive very urgent attention not only because such a development can pave the way for laying the foundation of biological studies in the school, but equally so for providing the means for adult education in biology for the village. In the preparation of these school texts in the different languages, the need is paramount for the adoption of standard terminology, so that technical terms

adopted will be the same throughout the country and as far as possible in conformity with international usage. I am aware that these questions are receiving the attention of Central and State Governments and a few Universities, but the pace at which things move could be accelerated only if we take more active interest. We have here Zoologists drawn from the various parts of the country representing different languages and it would be a very healthy development if we could work out standard terminology of technical terms in our own science and recommend them for general adoption.

DIFFUSION OF SCIENCES FROM CITIES TO VILLAGES

The diffusion of zoological knowledge can also be viewed from a different angle. Our centres of learning have mostly been in the cities where the older Universities originated and flourished; even the later Universities, owing to obvious other reasons, have developed principally in urban centres. The sciences have therefore come to be regarded as metropolitan learning. The task of popularization is again one of diffusion of scientific knowledge from the cities to the smaller towns and villages. In recent years there has developed a movement for starting affiliated colleges in the smaller Provincial centres and this should help a great deal in the dissemination of scientific knowledge, but actual results will fail to be achieved if we are not able to find some suitable method for large scale efforts at popularization. Two possible lines of attack can be indicated, the Provincial or District Museum and the local Scientific Society.

MUSEUMS

In India we are fortunate in having some of the oldest of modern museums and these institutions have played a very important part in the development of biological sciences. Special mention is necessary of the Indian Museum at Calcutta, the Madras Museum and the Prince of Wales Museum at Bombay. Other Provincial Museums were later developed with varying amounts of emphasis on Natural History. Here again zoological and botanical interests were often sacrificed for the sake of the more spectacular achievements in our ancient history and prehistory. Apart from this, the museum movement has not kept pace with the rise in literacy and general level of education. While older museums have further grown or have just maintained themselves, the number of new museums which has sprung up is negligible and many large States, although having several important cities, have often nothing more than small museums at the seats of Governments. In the furtherance of zoological knowledge, it is very necessary for us to pay attention to the more active development of museums in the various important Provincial towns. The opportunities which villagers have for visiting the cities like Calcutta, Bombay and Madras are limited but most people at some

time or other will visit the headquarters of their own districts. What could be more desirable than the development of small museums at least in the principal cities of the more important districts? The question of raising sufficient funds is no doubt involved and to my mind it appears that it should not be difficult to surmount the financial burden if natural history museums in colleges are subsidized and developed into small Public Museums. Zoological gardens and aquaria are culturally part of museums and their development should also proceed side by side. There is room here for active co-operation amongst Provincial University or Colleges, the District or other Local Boards and the State Government in the development of a most effective instrument in adult education.

THE LOCAL NATURAL HISTORY AND SCIENTIFIC SOCIETY

I wish now to refer to another valuable agency for the development of our science which, speaking for the country as a whole, we have hardly developed. In all countries the local natural history and scientific societies began to develop soon after the time when interest in biological sciences began at the Universities. These institutions, often from very humble beginnings, have played a significant part in the growth of natural history and field studies and have substantially contributed to the growth of biological ideas. Many European countries smaller than some of our larger districts have several societies which work for the promotion of zoological studies, especially among those who may not have had an orthodox training in Zoology. They periodically meet, exchange collections, organize expeditions and publish the scientific results, however imperfect they may be, reported by the members. These societies have kept the subject alive in the minds of people whose occupations may be varied and remote from science by providing opportunities for pursuing their natural history interests as a hobby. In fact these institutions have and do still provide serious pleasure to a large number of culturally active individuals whose collective achievements in the accumulation of scientific information would rank very high. In our country a very remarkable record of unbroken service to the cause of field sciences is that of the Bombay Natural History Society. The fifty volumes of its Journal which this Society has published out of its own funds bear ample testimony to what can be achieved by the enthusiasm and interest of persons, not necessarily scientists, who, although mostly in other occupations of life, have been able to take such an abiding interest in Natural History.

It is, however, unfortunate that considering the size of the country and the scientific opportunities available both to the trained Zoologist and to the amateur naturalist, the scientific societies in existence are so few; even those existing are not so sufficiently patronized as to enlarge the scope of their activities or to undertake projects which involve financial outlay. A few societies which exist in connection with Colleges or

Universities are too classroom-minded to be effective as dispensers of biological knowledge; most of them lack continuity of effort. I wish to place before the younger zoologists scattered throughout the country the idea that if they could organize smaller bodies or working parties to study animal life in their own centres and enlist the enthusiasm of non-zoologists as well, they would probably have given a good start in the diffusion of zoological knowledge from the seats of learning to the people.

ZOOLOGY OUTSIDE THE CLASS ROOM—FIELD ZOOLOGY AND ECOLOGY

Backwardness in Field Studies.

Rise of Modern Ecology.

The reference which I have made to the part which natural history societies could play in the spread of zoological knowledge leads me to discuss the backwardness of field zoological studies in India. Field zoologists amongst us are admittedly few. Even among those who have taken to zoological work as a vocation, those familiar with our aquatic or bird life or insect fauna are not many. Often their handling of the subject in the class room is divorced from the animal life around them. It is a common experience to find many teachers of zoology preparing students for Degree being unfamiliar with the common birds or insects frequenting the area where their laboratories are situated. Fewer persons take interest in pond-life or marine life. The teaching is mostly the reporting of facts from the pages of text books. The defect no doubt has to be traced to the class room where many of the teachers have been trained and the lack of attention to that essential aspect of zoological work viz. observations on living animals. The science of zoology includes both the descriptive aspects of natural history and the quantitative expression of these qualities based on the finer analysis in the laboratory. The extensive work of many keen students of natural history during the last century formed the basis of ideas of natural selection and evolution. For many years zoological science has remained a descriptive science but in the last four decades has occurred an immense expansion in the analytical work on zoological problems by the extensive application of methods belonging to the exact science of Physics, Chemistry and Mathematics. This impact of exact sciences on the descriptive sciences has no doubt been a most beneficent influence which has broadened the scope and outlook of our subject. We are all agreed on that. But there is a tendency among a large proportion of our zoologists to forget that the greatest laboratories available to them are those provided by nature. The Louis Agassiz dictum: "Study nature, not books" may well be recommended to many whose familiarity with the subject lies within the class room, books, museum and laboratory specimens. The casual observations on the habits of an animal here or there, while good, may not lead to great strides of knowledge but most important findings await observers who by

the application of quantitative measurements, study the animal populations in relation to their surroundings under natural conditions. The rise of modern ecology during recent times is a landmark in the development of our science, thanks to the pioneers like Shelford and Allee in America and Elton in Britain. Earlier ecology consisted of the enumeration of plants or animals forming communities. A closer relationships was attempted in later studies but at the present time, we are in possession of techniques enabling us to proceed with the quantitative assessment of populations, their interactions and their evolutionary responses to changing conditions. Field Zoology as we now understand can extend from the simplest observations of natural history to the most intricate analysis of dynamics of animal populations. It is a wide enough field for all students of our subject ranging from the amateur naturalist to the most accomplished laboratory scientist.

MARINE BIOLOGICAL STATIONS

In his Presidential Address to our Section in 1942 at Baroda, Dr. Rao has laid emphasis on field studies with particular reference to marine biological stations. The value of facilities for studying marine life as an aid to the teaching in the Universities, and for providing adequate facilities to workers on fundamental problems has been fully indicated in his address. Since that time, we have made some progress, admittedly small, considering the number of Universities and Institutions which have sprung up for teaching Zoology all over the country. A Marine Fisheries Research Station has been set up by the Government of India at Mandapam with considerable facilities for marine work while the Government of Bombay have opened the new Taraporewala Aquarium at Bombay. In both these institutions, facilities available for visiting students and workers from Universities are very much limited owing to various reasons, the most important of which is that these are primarily fishery institutions; pure research and instruction in marine zoology can play only a minor role. With these new institutions and the existing centres at Trivandrum and the Krusadai Islands, opportunities of field teaching have somewhat extended but are still very inadequate. As so strongly advocated by Rao, more institutions should come up and better facilities have to be provided in the existing institutions. There has also been an increasing interest in the advancement of oceanographic studies in the country. The greatest obstacle to progress is the absence of Research Vessels for making observations in off-shore waters but the recent expansion of power fishing projects now receiving the attention of the Central Government may probably provide opportunities for marine work both on the applied aspects of fisheries and on the fundamental aspects of marine science.

FRESH-WATER STATIONS

While we have many potential centres for marine studies which could

be developed, we have relatively few centres for developing studies on fresh-water biology on any extended scale owing to the absence of large fresh-water lakes. Our limnological problems are not those concerned with lakes but with rivers and tanks and in the selection of suitable centres we should be guided by that principle. The development of the reservoir at Mettur for fresh-water biological work, as advocated by Dr. Hora, should receive the active support of scientists because of the special advantages offered by the site; other centres suitable for riverine problems may exist in the States of Uttar Pradesh, Bihar and Assam. It is to be hoped that the Universities of these States will pay attention to the pursuit of fresh-water biological studies and develop suitable centres.

ESTUARINE STATIONS

The geographical peculiarities of our country provide a biological complex offering excellent opportunities for field studies which it is hoped will be more fully developed and utilized by our workers. This is the estuarine biotope. Pioneer work has been done on the fauna of estuaries and backwaters of India by Annandale and Kemp by the study of the Chilka Lake; other investigators have followed in Bengal, Madras (Adyar) and Travancore and we have a fairly good idea of the major elements of the fauna of the backwaters and estuaries of these tracts. It should now be possible to open up more extensive field-biological and physico-chemical studies on the estuarine environment, leading to a correct evaluation of the faunal elements in relation to the habitats, based on intensive quantitative observations. The extensive river systems of the Godavari and the Krishna remain completely unexplored and it is to be hoped that Zoological Institutions coming up in the Andhra area will develop studies on these rivers which will be of great interest in the development of tropical aquatic biology. The Chilka and Pulicat Lakes, both having very valuable fisheries, yet remain to be investigated from the standpoint of quantitative ecology and production of life. The field material available to us for aquatic biology is very large and should commend itself to zoologists working in centres where natural facilities exist for such studies.

TERRESTRIAL ZOOLOGY AND ECOLOGY

It is an unfortunate coincidence that field studies relating to aquatic zoology have generally received more attention than those relating to land and I wish to place special emphasis on the latter because the vast majority of our zoological centres are situated in places where unrivalled facilities exist for carrying out projects in terrestrial ecology. The usual demand is made by zoologists for the starting of marine biological stations and fresh-water biological stations. Both are no doubt of the highest importance, but in my opinion, of equal value are field stations for the prosecution of studies on terrestrial problems. Geographical and climatic

diversity has bestowed on us a wide variety of terrestrial habitats, each presenting biological problems of special interest. We have as yet made very little progress in developing entomological field stations in the strict sense although we have a few excellent centres for entomological study. Such field stations should not be devoted to the experimentation of particular species, but to the development of a natural fauna where one may observe and follow the mutual inter-dependence of life. Other problems of terrestrial zoology which we ought to develop are the ecology of forests where there is much to learn of the differences in the faunal associations and succession of areas subject to divergent macro- and micro-climates and the influence of the substratum. The bio-ecology of the tropical rain forests like the Western Ghats on the one hand and mountain ecology of high altitudes as in the Himalayas should receive attention at the hands of our workers. A very necessary and new line of work on the zoology of arid areas remains to be developed and it is to be hoped that the Rajasthan University will foster a school to devote to the special problems of that area. We are often inclined to learn Zoology as a subject in itself forgetting the intimate bearing which our problems have in relation to geography and geology. We have no data on the zoology of our soils. Thanks to the work of numerous sportsmen and naturalists we have a fairly wide range of information on our birds and mammals. Their studies still predominate largely on museum taxonomy and natural history; we have yet to make a beginning in the study of wild populations of birds and mammals throughout the country.

If one visits a College or University, it is usual for us to hear the complaint that there are no facilities for research. This is in some measure true because in most centres essentially required literature is lacking; opportunities of meeting and discussing results with workers of comparable interests are few and often the time available outside routine teaching is small. But if we look more closely, it may be observed that in most centres, the existing natural facilities for making original observations on Zoology have not been utilized, and it is not uncommon to find interesting local zoological problems completely ignored. I shall attempt in the following paragraphs to examine how we may overcome the inherent deficiencies which retard progress in our centres of instruction of Zoology.

ZOOLOGY AT THE UNIVERSITY

The status of our subject in the country will ultimately depend upon its status at the University. As indicated in the earlier section, we have made much progress in the development of zoological studies in the country as a whole and at certain University centres under the leadership of some of our distinguished zoologists. There is, however, no reason for complacency; in fact there are many recent developments which have affected the quality of zoological work of the Universities. The fountain

head of learning is the University which trains people for work in all branches of zoological work. Anything which is damaging to the calibre of that training will mar our progress for a long time. There is first of all the need for assuring a steady stream of first rate men for imparting instruction in the subject and in the training of men for research. There is the equal need to bring out workers with sufficiently sound training to take on applied work in the country. Problems relating to our food resources like fish production, plant protection, food storage are intimately bound up with zoological problems. A vast applied field similarly lies in problems of medicine and public health. The efficiency of workers handling these problems is something of real consequence to the future of our country in the manner in which we are able to solve our problems. The responsibilities on Universities are heavy and onerous and I feel sure that all of us here would like to see everything done to maintain the standards of teaching and research at the Universities at the highest level.

STANDARD OF ZOOLOGY AT THE UNIVERSITIES

Retrospect

In subjects where rapid developments have taken place, high standards can be maintained only if the courses of studies and methods of teaching fully take into account the recent advances. The trend of changes which have taken place in our subject could profitably be indicated here. Earlier workers concerned themselves with the structure of animal life, the different kinds of organisms and the patterns into which living organisms could be classified. Taxonomic zoology thus had an early beginning along with the development of the morphological concepts. Then came the emphasis on variations and its causes—studies which in the hands of Darwin and Wallace developed into the concept of Natural Selection and the process of Evolution. It is universally agreed that the law of organic evolution is the greatest generalization ever made in the field of biology. As a result of the impact of the concept of evolution, the whole field of zoological work was transformed into the search for factual data in support of evolution. Comparative anatomy and embryology rose to prominence and dominated the scene until a new orientation was given to zoological work by the development of experimental techniques. The transformation which has taken place in our subject is the slow emergence of Zoology as an experimental science—by the shift in emphasis from form to function and from qualities to quantities. The change in outlook has permeated every branch of Zoology; even the old type of morphology has given place to functional morphology; the old type of taxonomy has given place to the more refined "new systematics" giving emphasis to quantitative assessment of characters and a closer appreciation of scope of variation of individual characters in animals and plants. Modern Genetics has developed into a new science where advances have been most rapid, chalking out paths of progress on

independent lines. Similarly the new discipline of comparative physiology has emerged and has eclipsed comparative embryology. Assimilation of ideas developed in recent times in physical chemistry, biochemistry and biophysics has resulted in deep and fundamental changes in the nature of biological investigations. The Zoological Science of to-day is a very different discipline from what it was thirty years ago.

DEFECTIVE CLASS INSTRUCTION

Let us examine how far these modern developments in Zoology have found expression in the courses of zoological instruction given at our Colleges and Universities. With the exception of a very small number of centres, where the individual enthusiasm of a professor or a lecturer has resulted in modernized instruction in the fields of study handled by him, we have to admit that teaching of the subject in most places has not taken into account the advances made in recent times. We still find that the major portion of the lectures is devoted to purely descriptive accounts of the various phyla leaving practically no time to treat the general principles of Zoology. The trend of lectures given is often such as to get lost in a mass of details at the expense of fundamental ideas. The structure of organisms is often described with complete omission of any mention of their function. The type system of study is often carried to fantastic limits without any broadbased treatment of the evolutionary concept. Our practical classes in Zoology still place greater emphasis on technical skill in the dissection and display of various systems rather than in practical demonstrations to understand the functional morphology and significance of the various organs. To make matters worse the examinations in theory and the method of conducting practical examinations have all come down to a question of feats of memory or dexterity of hands without enough regard to knowledge of real Zoology. No wonder then that examination results are often misleading and give no reliable idea of the capabilities of the student for zoological work; much less do they indicate the aptitude of students for original observations and study. Courageous zoologists here and there are struggling to keep an even course but it is mostly found that University bodies which have to decide on syllabus and methods of teaching are mostly dominated by teachers who are unwilling to adapt and modernize the courses of studies.

LANGUAGE PROBLEM

I have already referred to the language problem as a serious barrier to the diffusion of knowledge. We are again confronted with the same problem in a different context. English remained the medium of instruction in Science in schools and colleges for a long time. With the regional language taking its place in the school almost throughout the country and to varying extent in the different University classes, we are faced with the problem of finding an effective medium for imparting zoological

instruction. Hindi has already been adopted at a few University centres, a necessary step in the right direction in principle; only actual experience will show whether the language has an adequate vocabulary for the complete change over from English. I am aware that opinion on these and related topics is divided and it is not my desire to tread this controversial ground. What we, zoologists, are deeply concerned is that so long as a medium is not effective for imparting instruction in our subject, the standard of teaching is bound to deteriorate. Even in Universities where the subject continues to be taught in English, there has been a fall in standards owing to the all-round deterioration in the proficiency of the English language, limiting the capacity of the pupils to learn a subject taught through that medium. These are problems which we have to face and discover the means for tiding over the difficulties of the transitional period without delay, because the damage is already evident.

VALUE OF EXACT SCIENCES

We are faced also with other inadequacies in the intellectual equipment of our students which should be removed if we are to give a new orientation to zoological teaching. The training in physics, chemistry and mathematics which students of biology now have is woefully inadequate and often makes it difficult for them to follow developments in comparative physiology. Mathematical background is likewise poor proving a serious handicap in the application of finer methods of statistical analysis. Most biologists are poorly equipped to handle applied zoological problems owing to this defective training even though their training is sufficiently high to pursue descriptive studies. It would be a desirable development if it is made essential for students taking biological studies to have a substantial grounding in the exact sciences; this will have a healthy effect in developing the very necessary quantitative outlook to workers who have to deal with much that is descriptive and qualitative. I would in the same manner advocate some amount of biological training to those taking up the exact sciences as their fields of study which would certainly help them consider living organisms something more than a bundle of physico-chemical laws.

HUMAN FACTORS

There are many directions in which improvements are desirable and even necessary in order that the standard of University work and teaching may be raised. The question of adequate equipment, provision of good libraries and reduction in hours of teaching duties so that teachers will have time for original investigations are all well known to need emphasis although the number of institutions paying sufficient attentiin to them is regrettably small. To this may be added the question of conditions of service which at most institutions demand improvement. The importance of the human factors in furthering creative efforts is generally ignored

by most persons in our country; apart from monetary considerations there are many other factors which would help a scientific worker to feel that he is in his proper *milieu.* Official routine and time consuming administrative responsibilities tend to reduce the enthusiasm for creative work in many promising workers while agencies that foster free discussion of zoological work and stimulate the flow of ideas are few.

EXCHANGES AND EXTRA-UNIVERSITY CONTACTS
Importance of Fundamental Research.

The stimulus that intellectual work would receive by travel and contacts with new surroundings and workers not normally available, will be invaluable to the development of our subject and the tone of teaching our Colleges and Universities. Annual conferences like the Science Congress do help but they are not enough. We have not yet realised the value of exchange of Professorships, Lecturerships and even Tutorships between our centres of learning. In the teaching of Zoology and more especially with emphasis on field studies as I have tried to indicate, the experience which University teachers would gain by visiting other centres would substantially help them develop a wider outlook in their teaching and, more than that, it would help them extend their research studies. We have to aim at something more than casual visits. All institutions would benefit by the stimulus of a teacher from a sister University coming and spending an academic year with them and taking full share in the academic responsibilities. Unfortunately the managements of institutions and Universities take too rigid a view of the conditions of work of their staff as to make such interchange of personnel extremely difficult. But I feel confident that if we as a body of scientists exert sufficient pressure and make the advantages of such interchange obvious it should not be difficult to work out such exchanges in teaching and research staff. I would even suggest that these exchanges should be extended to spheres of work of pure research departments. The applied scientist in the research department would stand to benefit by his association with workers dealing with fundamental problems at Universities and draw inspiration from such work which is not subordinated to finding solutions for practical problems. Similarly, the fundamental scientist at the University will by his contact with applied workers be in a position to appreciate the significance of practical problems that arise in the application of scientific results. In our own science two fields in which active co-operation between University centres and applied institutions would be most desirable are in the fields of Fisheries and Entomology. In these two subjects there is scope for work on purely fundamental lines for the University Scientist and for the applied worker who is more concerned with the perfection of methods to deal with the practical side of fisheries problems based on his field data. The need for close co-operation is

equally obvious in the field of entomology where the vast array of taxonomic and physiological studies without any regard to whether an insect is of economic importance or not could be developed at the University giving the starting point to the applied entomologist to develop his studies with reference to specific species. Applied workers are generally concerned with problems of very restricted scope and the emphasis mostly given is on the abnormal and not the normal pattern of relationship among living organisms, like for example, the depletion of of fish stocks, fish culture or heavy infestation of of crops by pests. Let us not ignore the basic fact that substantial advance in knowledge in any branch of science will be possible only with the development of fundamental work and the development of basic ideas. There has developed a recent tendency in many institutions to draw distinction between what is called pure and applied research. Let us not compromise on this issue. Sharp demarcation between what is fundamental and what is applied is not possible nor desirable and sound development of applied sciences can rest securely only on the firm foundation of pure knowledge.

PUBLICATION OF ZOOLOGICAL PAPERS

Before concluding this address I should like to focuss attention on another serious difficulty which active workers in Zoology are experiencing in this country. This relates to the inadequacy of facilities for the publication of results. With the increase in the number of workers and output of work the existing Journals are not in a position to deal with the amount of publishable material that is completed at the various centres. Increasing cost of printing and production of Journals has already resulted in some of our Journals being forced to reduce the annual output of pages. The time lag between the completion of a paper and its actual publication is often discouraging for most workers. I am aware that many pieces of good work completed at University centres remain unpublished and this is certainly an indirect waste of national effort. There is in addition a tendency among a section of research workers not to take the same interest in the publication of results as in obtaining Research Degrees. As is done in some Universities abroad, the time has probably come when it would be desirable to make it obligatory on the part of the recipients of Degrees to get their papers in publishable form acceptable to the University for independent publication or to any scientific journal. Such conditions can be insisted only after sufficient provision has been made for expanding the scope of the Journals or by the opening up of new avenues of publication in the country which should also maintain the highest standards as regards the quality of the material published. The inadequacy at present felt can be met with only if increased financial support is given to our Journals and the National Scientific Societies that run the Journals.

CONCLUSION

In this brief address I have attempted to place before you some of the problems facing us. As zoologists we are anxious to see that we make progress in zoological work in the country on sound lines. These questions have been discussed not because I have immediate solutions for submission, but because these difficulties are real and call for our collective efforts. There is need for free and frank discussion on how best we may deal with them. I conclude with the hope that by such discussion, exchange of thoughts and their eventual translation into practice, we may develop an active interest in Zoology among our people, improve the tone of teaching and research at our centres of learning and thus pave the way for the development of original ideas and work in conformity with the natural facilities available in the country.

40th INDIAN SCIENCE CONGRESS, LUCKNOW, 1953

SECTION OF ANTHROPOLOGY AND ARCHAEOLOGY

President : PANDIT MADHU SARUP VATS, Hon. F.R.A.S.

Presidential Address.

Archaeology in Post-Partition India

The Presidential chair for the Archaeology and Anthropology Section of the Indian Science Congress offered to me is indeed an honour and privilege which I greatly appreciate. It gives me an opportunity to bring to the notice of the learned audience here the concrete work that had been undertaken and executed by the Government of India, Department of Archaeology, and to indicate the nature of the responsibility that has rested on it in looking after the archaeological monuments—historic and prehistoric.

The political changes that came in the wake of partition in 1947 have necessitated a re-organization of the Department. The country was severed both along the eastern and western ends, the cut across the north-west running through regions of great importance so far as the chalcolithic cibilization of India is concerned. At the same time, this loss was more than compensated by the integration of States which have brought new responsibilities to the Archaeological Survey not only for the preservation of monuments of national importance but also for all other kinds of archaeological work in regions which now constitute Part B and C States. Five years after Independence and partition it is but proper that we should take stock of what we have achieved, what are our problems and what is our future programme.

At the outset, it is worth remembering that the Department as custodian of the archaeological wealth of the country has necessarily been occupied with the important task of conserving the monuments above ground. This responsibility has been considerably increased by the addition of some 520 monuments of national importance which have come to us for the first time on the integration of Part B and C States into the Indian Union. An extensive survey of the condition of these monuments will have to be made before it is possible to plan a scheme of putting those, which are in urgent need of special repairs, into a reasonably good state of preservation. Our task here is limited by two factors: (1) the speed with which these monuments can be surveyed and their needs studied in detail, and (2) by the amount of grants that may be available for the purpose. Another need of these monuments is their listing in a scientific manner, and this will necessarily include a good deal

of photographic and drawing work before we can feel that we have done our duty to these monuments. So far as exploration is concerned, a survey of these areas is equally necessary, but for obvious reasons this cannot have priority over the survey of monuments standing above ground, as this work can be postponed at least for a while. For the excavation of sites of national importance the Department has never had more than a limited organization, and this has led to selective excavation at some of the more important sites. Within the last few years, however, the Department has been affording necessary facilities of training to scholars and university students in the scientific methods and technique of excavation work, and to a lesser extent to outsiders in conservation work also. For excavation the Department has never claimed any monopoly, but it has been its aim to keep up standards of work, which may be follower by universities or other institutions interested in archaeology with the help of the personnel trained by the Department. Foreign archaeological expeditions have also been allowed to work in the country, as scope for such work is unlimited, and, with its present resources, the Archaeological Department could, at best, tackle only a few of the important sites.

The main problem in Indian archaeology has been, and still is, the filling up of the wide gap that exists between the proto-historic Harappa culture on the one hand and the early historic cultures of the north. The exact relationship between the Northern Black Polished Ware (N.B.P.) and the Harappa ceramics has not yet been determined. Nevertheless, within the last few years it has been observed that there is a wide distribution of N.B.P., which is no longer confined to the Gangetic Valley, and therefore this name is hardly appropriate now. Moreover, the colour of the pottery implied by the term N.B.P., is not always black, as it ranges from black through lead-white to a golden tint. Till a more comprehensive and acceptable term is adopted for the nomenclature of this ware, the term N.B.P. would refer only to the fabric without necessarily implying any particular colour or geographical definition.

Some fieldwork has lately been undertaken on sites which had been observed to occupy chronologically intermediate positions between the sites of the Harappa culture and those where N.B.P. has been found. Consequent on the loss of important Harappa culture sites in West Pakistan, it became necessary to explore sites of that culture along the contiguous parts within the Indian Union. Accordingly, a beginning was made two years ago, in Bikaner and this exploration it is proposed to extend, as soon as may be, to Jaisalmer and Cutch. In 1928, I traced the Harappa culture at Kotla Nihang in the Ganges-Jumna *doab*, and in 1936 a later phase of this culture at Rangpur, Limbdi, in the Saurashtra Union. These two outposts of the Harappa culture show its marked eastward extension into the Indian Union.

The more recent archaeological explorations conducted in the valley of the dried up rivers Sarasvati and Drishadvati—hallowed names in hoary past—in Bikaner have put on the map nearly a hundred ancient sites. These could be grouped into (1) an early series of settlements representing the culture of the Harappa-Mohenjodaro city states; (2) a group with Harappan affinities but slight differences in pottery fabric and types, suggesting an eastern variety of Harappa culture; (3) a group with painted greyware and associated pottery distinct both from Harappa wares and those of the succeeding cultures. This group corresponds to the painted greyware of PEPSU, East Punjab and West U.P., which have, of late, assumed importance as the potential interlocking key to the Dark Period. The painted greyware culture seems to have flourished in the first half of the first millennium B.C., (4) the last group comprises comparatively larger sites representing a culture characterized by sturdy and varied pottery, painted with black (or rarely crimson) on red ground, which perhaps flourished in the early centuries of our era. More work in this area is a real necessity and is sure to be highly fruitful.

The painted greyware itself had been excavated in an ideal setting and sequence at Hastinapur where the two seasons dig in 1951 and 1952 has unravelled five main periods of occupation. The lowest yielded a dull red ware with poor ochre wash, which seems to have its analogues in the pottery discovered at the Gangetic copper hoard sites at Bisauli, Rajpur, Parsu, Bahadrabad, etc., though this point requires further investigation. It was succeeded by the painted greyware, etc., associated with copper arrow-heads and the occurrence of a great flood, represented at the site by an extensive erosion of the mound, seems to have ended this phase. The occupation was again started in about 600 B.C., by the 'N.B.P.' using people who also used kiln-burnt bricks and ring-well soakage jars and had square punch-marked currency pieces of beaten silver or copper. This occupation seems to have suffered devastation by a great fire. But the site was again inhabited during the Sunga and Kushan periods, indicated by countless terracotta objects of the former and a few coins and Bodhisattva image of the latter. The last period of habitation came after a great lapse of time during the 11th century and continued for some hundred years. This culture was characterised by pre-Mughal glazed pottery with a coin of Balban (1266-87 A.D.) dating the phase. The painted greyware has been observed to occur at Ahichhatra, Barnava, Baghpat, Tilpat, Panipat, Mathura, etc.

Interesting facets of a late prehistoric culture, involving the occurrence side by side of red-on-black painted ware and microliths have been brought to light in a number of places in Western India, where N.B.P. also had been observed to occur. This indeed is a most welcome link in the chain of cultures that bind the cis and trans-Vindhyan country. The sites at Nasik, Bahal (East Khandesh), Jorve (Ahmednagar District)

have revealed a new culture which is characterized by painted ware in association with microliths and occasionally with urn burials. Such sites have also been observed further south at Sinnar and Bhojapur and indicate possible settlement of this culture along the Pravara, Bhim and Godavari rivers. This aspect of work might well engage our attention.

A new pottery type called by its explorers as the 'red polished ware' of superior fabric and slip has been reported from nearly 30 sites in Gujarat and Saurashtra. These include Somnath, Junagadh, Amreli, Venivadar, Valabhi and Baroda. Its apparent Roman influence and contacts and distinctive chronological horizon in the first three centuries of the Christian era in the so far excavated sites of Baroda, Vasant, Amreli indicate its value as a datum for pre-Chalukyan Western Indian archaeology. Outside Gujarat, such pottery is found in the Satavahana levels in the Deccan and Kushan levels in the North.

Many important copper finds, viz., chisels, celts, swords, etc., had been reported in the past from the Gangetic basin and even spread up to Central India—such as the copper hoard sites of Rajpur, Bisauli, Sirthauli and Gungeria (Central India). These had attracted great attention in the context of their likely bearing upon the Copper Age in the Gangetic basin. The latest discovery of this kind was the occurrence of similar copper celts, etc., from a spot on the Ganga canal near Bahadrabad (Saharanpur District, U.P.). The finds have been recovered considerably below the old Ganga bed and their further importance lies in teir seeming association with a ceramic industry of distinctive fabric. It is too early yet to speak any further upon this Bahadrabad site and finds. Further investigation concerning this important cultural epoch of the post-chalcolithic period in North India is underway.

Quite recently, and just by chance, welcome light has been thrown on the actual performance of the *aśvamedha yajnas* by the kings of old. The precious relics of these are from Kalsi, already well-known for its Asokan rock Edicts, and comprise partially damaged bricks belonging to the sacrificial altar of the fourth *aśvamedha yajna* as attested unequivocally by the clearly incised inscriptions on them. The sacrificial altar is called "chaitya" here, and it was the fourth *aśvamedha* sacrifice performed by a king named Śilavarman. Though nothing is known of this king from other records, we may infer, from the palaeography of the inscriptions, that he lived somewhere about 200 A.D. The inscription on the best preserved of these bricks (measuring 26″×12″×6″) inscribed on two sides clearly states that "this is the sacrificial altar of the fourth *Aśvamedha* (sacrifice) of the devoted king Śilavarman of..........60 years (reign) by the *"ganda"* reckoning (i.e. in units of four)".

We shall now turn to certain aspects of preceding millennia which demand our attention. The science of prehistory in India, despite the classic work of Drs. deTerra and Patterson and other savants is still in an

unsystematised condition. This branch of study, while deserving our earnest attention, had suffered owing to the lack of a co-ordinated and planned scheme of work covering its various stages. The countless palaeolithic and microlithic sites which have been discovered in various parts of South and Central India have lacked basic chronological sequences into which these could be fitted. A systematic study of the terrace gravels in some of these regions, as done to some extent by Mr. Burkitt for Kurnool, is necessary. It presupposes an intensive survey and study of the hitherto untouched regions along the river systems south of the Vindhyas. The proper correlation of the 'Sohan' and 'Madras' palaeolithic industries would involve the opening up of the Central Indian region from the middle Narbada basin to the Son river basin in U.P. and Bihar and Bastar in the south-east. Again, recent developments in the study of the microlithic element in Indian Stone Age would suggest that the Tinnevelley Teris, the lateritic conglomerate in the Madura and Sivaganga areas in the South, the Kurnool and Godavari districts and the Central Indian and Bastar regions are of potential importance. As regards the exploration of cave deposits for the unravelling of the Upper Palaeolithic Culture sequences in India, the ground is still practically untrodden and to all these aspects the Department has, in recent years, given its serious attention and intends doing planned work in the years ahead. A beginning is being made in this direction in the Bastar area.

It would appear that right down to the Asokan times, large parts of Penninsular India were inhabited by populations comparable to the more primitive, present-day aboriginal tribes given to shifting cultivaton, who were using the neolithic celt with pointed butt and oval cross-section and living in more or less permanent houses as evidenced by the neolithic strata of the Brahmagiri excavations. It is, however, difficult to trace the ancient neolithic sites and, in this, it seems that the probability of a present-day settlement in close proximity, to ancient sites could hardly be expected as a matter of course. However, carefully conducted small scale excavations in selected primitive tribal settlements—particularly of the Bondos and Gadabas of Orissa, Mundas of Bihar, Khasis of Assam and Kotas of Nilgiris—may at least give us comparative data which may be valuable to make progress in this problem possible. This is a task in which we should like to be associated with anthropologists. As regards the study of the distribution of the oval sectioned, pointed-butted celts and their relation to the early agricultural communities in India, a racial or linguistic linking has to be attempted. For instance, Professor Heine-Geldern held the view that the Proto-Dravidian languages have to be assigned to these early neolithic cultivators. But the people of the intrusive Iron Age Culture in the 3rd century B.C., as demonstrated at Brahmagiri and Sanganakal (Bellary), could not but have also spoken the same language. One would be inclined to suppose that the builders of mega-

liths were the speakers of the Proto-Dravidian languages as they seem, from many points of view, to be the immediate predecessors of the historic Dravidian civilization. Besides, the megalithic funerary monuments of South India, probably of western origin are of an altogether different culture from the memorial megaliths of Assam and N.E. India which seem to have been relics of an Eastern Austro-Asiatic culture migration. An overlap of thees two would be possible in the Baster and Godavari area. Thus, from more than one aspect this region seems to hold the key for the evidence concerning ancient agricultural communities of India. Side by side with this extensive fieldwork, study of the occurrence of neolithic celts in the Salem and South Arcot districts of Madras State would also definitely enrich our knowledge of Indian neoliths further and help in the correlation of the neolithic and megalithic cultures in this part of the Penninsula.

The Megalithic Culture of South India has long been the fertile ground upon which sporadic researches and fieldwork had been conducted by scholars and amateurs alike during more than half a century. But until 1947 its proper chronology had been very elusive when in the Departmental excavations at Brahmagiri, Mysore, it was traced in an interlocked sequence with a lower neolithic culture and a higher Andhra-Satavahana Culture. These Iron Age funerary monuments, however, appear to have been a sudden intrusion in this area. The structural nature of these monuments differs from region to region with local geological environments; consequently the funerary containers and contents have also varied. While in the extreme South pure urn-burials in extensive urn fields—as at Adichanallur and other places—have been met with, dolmenoid cists or regular port-holed slab cists occur as we come north. Besides, the funerary container itself is prevalent in the form of a terracotta sarcophagus or urn, and is found in the dolmen or the port-holed slab cist. There are sites, as at Brahmagiri, where the funerary furniture has been placed directly inside the slab cists which are without any containers. The nature of the burial also varies: it is sometimes a fully articulated or flexed burial and sometimes a secondary, post-excarnation, fractional burial. In all cases, however, a large number of iron objects form a characteristic feature of these monuments, with some gold, terracotta and shall objects, besides a highly specialised 'black-and-red' type of pottery of countless shapes. These facts are known from the recent excavations conducted by the Southern Circle at Sanur (Chingleput district) in a megalithic site. A detailed report of these excavations is under preparation.

In the South, clear habitational mounds not being easily traceable due largely to the spread of extensive cultivation that has gone on for years, there is usually a plethora of megaliths which are not related, at present, to contemporary habitations. Nevertheless, there are a few

sites among which Senga Medu, near Vriddhachalam (South Arcot district of Madras State) is one which seems to offer good possibilities for a linking up of the Megalithic Culture with its preceding and succeeding epochs in this part of the country. This problem is being taken in hand by the Department.

Considerable spade work has been done in the various Circles comprising the Department in the discovery of historic cultures. For instance, the excavations at Garh mound in Vaisali had exposed an original mud rampart, associated with N.B.P. and Sunga terracottas (about 200 B.C.). The latest phase of the site was of the post-Gupta times (7th century A.D.) with brick built houses. Various antiquities like beads, terracotta figurines, sealings, as also N.B.P. and a variety of red ware pottery in another mound nearby would open up correlation between this area and Hastinapur, Kausambi, Rajgir, etc. At Kumrahar, the site of the ancient Mauryan Capital, excavation by the K. P. Jayaswal Research Institute clarified a few problems regarding the Mauryan pillared hall that had been encountered by Dr. D. B. Spooner in his excavation at the same site in 1912 and the following years. A Buddhist *vihara*—called *Arogya vihara* from the inscribed sealing and pot—of the Gupta times has also been brought to light. Other interesting features include a series of drains and massive defence walls in the earliest phase pertaining to 200 B.C.

The Allahabad University excavation at Kausambi, for which assistance was given by the Survey, has supplied us with a number of cultures ranging from the 2nd century B.C. to the 5th century A.D. and here one of the important discoveries was the identification of the *Ghositarama* found inscribed on sculptures and seals.

In connection with the South, a passing reference may also be made to the recent contributions to the mediaeval period by the Department. At Hampi, capital of the once flourishing Vijayanagara Empire, a small scale excavation in 1950-1 was necessitated by the expansion of the Tungabhadra Project. For the first time this gave us a corpus of Vijayanagara pottery and brought up numerous antiquities including gold coins, small images and beads. The report of this work is also under preparation.

As stated earlier, the primary task of the Department is conservation. By far the largest part of the annual budget-grant is spent on the maintenance and upkeep of monuments of various types such as rock-cut temples, shrines, stupas, mosques, tombs, palaces, forts, etc. Their variety raises equally varied problems.

To mention only a few, where, of late, outstanding major conservation works have been executed, I would refer only to the special repairs at the Taj and Fatehpur Sikri at Agra, the Gol Gumbad at Bijapur and the rock-cut temples at Kanheri and Elephanta, off the coast of Bombay

The international reputation of the Taj warranted the constitution of an Expert Committee to report on thorough measures of conservation for Shah Jahan's 'dream in marble'. The recommendations of the Committee are being implemented stage by stage. The work so far completed comprises water tightening the drum and dome of the main mausoleum, replacing almost all the pillars and broken lintels of the four octagonal pavilions round the main dome without dismantling or interfering with their entablature which was in a sound condition, reterracing and restoring the exquisite inlay work at the necking of the dome, the *chhattris*, upper parts of the parapet and the marble platform in the centre of which rests the mausoleum.

At Fatehpur Sikri, the deserted capital of Akbar, the Buland Darwaza and the lofty walls on the south and east of the Dargah complex, the tomb of Sheikh Salim Chisti, the underground drainage and the entire basement were thoroughly repaired. The southern half of the entire terrace in several storeys was dug out and re-laid involving the use of 600 tons each of rubble and concrete.

The Gol Gumbad at Bijapur was also one of the major items of conservation. The dome had developed a number of cracks. Thick patches of plaster had fallen from the soffit of the dome and the accoustic properties of the monument were affected. After grouting the cracks, the monument was secured on the outside by means of a gunite shell and steps have recently been taken to treat the dome from inside with a doubly-reinforced gunite shell resting on a tapering ring-beam of reinforced cement concrete.

The rock-cut temples on the island of Elephanta and Kanheri near Bombay presented another type of conservation problem, namely, the decay or disintegration of the rock due to the continuous supply of injurious salts by sea breezes. Following the report of an Expert Committee extensive measurs for the conservation at Elephanta and some of its unique sculptures have been taken; cracks have been grouted and the entire rock surface covered with a coat of gunite. The remedy, however, will have to be repeated from time to time.

Similarly, the mighty problem of preserving the famous sea-shore temples at Konarak and Mahabalipuram still remains to be tackled. At the former, the work being of a highly specialised and technical nature, the Government of India have appointed an Expert Committee to grapple with the problems and on this the collaboration of other scientific Departments is also sought.

There is yet another aspect of our great national heritage. The care and proper maintenance of our outstanding monuments can bring in a lot of indirect revenue to our country by fostering tourist traffic, and it can also inspire in them respect for our past achievements on which we, as a nation, may build our future.

The important bearing of Chemistry and Physics upon scientific archaeology, not to mention geography, botany and biology, has brought in new aspects of investigations and the Chemical Branch of the Archaeological Survey, besides its active pursuit of the conservation of rock-cut monuments, stone sculptures, stuccos, wall paintings, etc., has recently been devoting attention to the need for the application of modern methods like Geochronology, etc. It has, since long, been conducting research on stone preservatives. One of the important causes of decay of lithic monuments is the presence therein of soluble salts due to one or another reason. True, while no chemical preservative can offer permanent protection to the decaying, cracking or exfoliating rocks, which have lost their cementing material due to leaching, chemical alteration within the body material brought about by climatic or other causes, repeated applications, at varying intervals, of suitable preservatives will nevertheless much retard, if not prevent, for a long time the decay of any works of art which it may be considered necessary to preserve. Cost, however, is necessarily an important factor when the application of a preservative becomes imperative on gigantic seaside monuments like the Konarak temple, Mahabalipuram monoliths, Elephanta caves or other large-scale monuments. Synthetic resins like Vinyl Acetate, methyl-metha-crylate, silicones, etc., are being experimented upon to examine their suitability and limitations, and if emulsions of synthetic resins could be made the cost of their application will be materially reduced. Moreover, with each successive application the quantity required will progressively decrease.

Systematic chemical treatment of wall paintings at Tanjore, Sittanavassal, Tirumalaipuram, Bijapur, etc., and Mughal monuments is being carried on by the Chemical Branch on the lines adopted in the West with suitable modifications due to local climatic conditions in India and there is urgent need for a proper study of the frescoes in the Ajanta, Ellora, Pitalkhora and Bagh caves with a view to the preservation of these masterpieces, besides the paintings at Lepakshi and palaces at Padmanabhapuram, Mattanchari, Chamba and elsewhere. Other aspects of research, which require investigation by the Chemical Branch is a complete study of the storeyed past of Indian ceramics and glazes, their technique and fabric and the conditions of their manufacture. Similar investigation into the realm of ancient Indian metallurgy is also called for.

The laboratory of the Chemical Branch is being re-organized for making a beginning with the application of Geochronological methods to Prehistoric sites as part of the programme of the development of Environmental archaeology in India, which is sure to help Prehistoric fieldwork substantially. Unfortunately, lack of laboratory facilities in India does not allow us to test the applicability to Indian conditions of certain physical methods that are being evolved in the West, e.g., archaeological dating by radio-active carbon, the progressive accumulation of fluorine in archaeological specimens, etc.

The nascent National Museum of Art and Archaeology has added to the volume of the Chemical treatment of silk, paper paintings, manuscripts, textiles, wooden and metallic objects and their cleaning, sterilization, exhibition and storage involve a careful study of the organic contents of the exhibits. Scientific recording of the humidity and temperature conditions helps in the knowledge of the conditions suitable for their storage. Besides these, in order to detect the repairs, fakes, obliterations, etc., in paintings and manuscripts, introduction of infra red, ultra violet and X-ray examination open up an altogether new branch of study in India. Such and other methods which will enable us to preserve valuable relics will continue to be the concern of the Department.

The importance of Epigraphy in the reconstruction of history can hardly be over-emphasized. India particularly is extremely rich in these records, whether on rock, pillars, monuments, copper-plates, statuary, pottery or terracotta. Estampages have been prepared of a large majority of such records, and it would be appreciated that if a greater speed in their publication has not been possible, that is mainly due to financial limitations. Nevertheless, by adopting a judicious system of priority the more important and spectacular epigraphs have been published every now and then in the Epigraphia Indica and other journals. In recent years, some interesting copper-plates have been discovered of which the following deserve mention:—

(1) Four new Bhoja plates from Bandora, Goa (2 sets) of Prithvi Vallabha Varman of Bhoja family which shed light on a hitherto unknown dynasty ruling around Goa during the 4th-7th centuries A.D. (2) Andhavaram plates of Anantasaktivarman of Kalinga *Mathara Kula* (5th century A.D.)—the second known charter of this king, the first being his *Sakunaka* grant.

(3) Fifty-five Karandai Tamil Sangam plates from Tanjore weighing over 216 lbs., recording a charter of Rajendra I Chola, in his 8th regnal year, with a Sanskrit preamble in verse which gives some hitherto unknown facts in Chola history, such as Parantaka I encountering a Pallava king, and the Kamboja king sending his *ratha* as a friendly present to Rajendra Chola to avoid war with the latter.

The stone records include the Baghora prakrit inscription from Jubbulpore district (2nd-3rd centuries A.D.) belonging to Vasithiputra Sivaghosa, Bhadrak Prakrit record of Maharaja Sirigan giving a hitherto unknown king's name and his sway over Utkala *rashtra*.

The Annual Reports of South Indian Epigraphy have been completed up to 1945 and are under print, while Annual Reports of Indian Epigraphy have been brought up to 1948 and are also under print. More than half of the fourth volume of Corpus Inscriptionum Indicarum by Prof: V. V. Mirashi, dealing with Chedi-Kalachuri inscriptions has been printed off. The manuscript of the revised third volume of Gupta inscriptions, which

had been entrusted to Dr. D. R. Bhandarkar was made over to us by him shortly before his death, which we all regret, and is now being revised and made press-ready by our Epigraphical Branch.

The constitution of Part B and C States has compelled new territorial and administrative arrangements in the Archaeological Survey. While its existing seven Circles were spread out over an area of about 7.3 lakhs square miles, the integration of princely States has added to this an area of 3.9 lakhs square miles. As it is our primary duty to protect and preserve monuments and sites of national importanne in these States, many of which either had no Archaeological Departments of their own or had them mainly in an advisory capacity, it is the statutory obligation of the Central Archaeological Survey that it should re-organise the Department so as to embrace the entire Indian Union. In pursuance of this, most of the existing Circles are expected to be realigned and their territorial limits readjusted as far as possible, on considerations of cultural homogeniety, administrative facility and economy. The proposed set-up would imply a somewhat larger organization than at present and is calculated to bring about a clearer visualisation of the local archaeological problems and a better planning for tackling the same. Needless to say, that all this arrangement to be operative would take some time and mean further financial commitment to the Government of India. But that these are imperative, nobody can deny.

Having briefly given a bird's view of the archaeological potentialities and problems of post-partition India, I would like to put forth a special plea on this opportune occasion, for an increasing collaboration by other scientific departments of the Government. No three branches of scientific study are more closely allied than the Archaeological, Anthropological and Geological Departments, and in varying degrees and for different chronological epoch these three sciences could, with advantage, co-operate in the successful exposition of the more ancient civilizations of India, their authors and their material culture. It is only in the proper utilization of the rapid advances made in modern sciences—natural, physical and chemical—in the proper appreciation of the limitations of mere accumulation of the handiworks of the past, in the introduction of methods like palaeomagnetism, geophysical prospecting of archaeological settlements, statistical analyses of pottery and artefacts, in the study of the climatic and geographical factors in ancient cultures—that Archaeology can hope to become more accurate in its speculative excursions, and sometimes arbitrary conclusions. With the great strides that archaeological techniques have made in excavation, exploration and the study of ancient relics, in other countries and in India, and with greater help from the more accurate sister sciences, I have no doubt that Archaeology would fulfil its real

function as the prime interpreter of the endless succession of unique achievements of the human brain and arrange in proper sequence and order, the tumbled episodes of human history and prehistory and present a conspectus of the common intellectual inheritance to the living man.

40th INDIAN SCIENCE CONGRESS, LUCKNOW, 1953.

SECTION OF MEDICAL & VETERINARY SCIENCES.

President:—Dr. S. DATTA, D.Sc., M.R.C.V.S., D.T.V.M., F.R.S.E., F.N.I.

CONTROL OF EPIZOOTICS IN INDIA

"The weaker the cattle, the scantier the production, the feebler the nation".

I have great pleasure in welcoming you to the deliberations of this Section of Medical and Veterinary Sciences. I must thank the Sectional and the Executive Committees for electing me to preside over the present Session. I consider it not only a singular honour, but a great privilege and opportunity as well, since it is not often that a scientist in the veterinary field is called upon to do so in this joint Section. This election is obviously a token of the intimate kinship and essential unity of medical and veterinary sciences which make our closer collaboration indispensable, and in the context of our present day problems all the more imperative. I take this opportunity thesefore to make a brief reference to the origin of the healing sciences and to emphasise how the development of one has invariably helped in the development of the other.

THE EVOLUTION OF THE CONCEPTION OF DISEASE

Diseases and evolution of measures to fight them have been an ever-engrossing problem since the earliest times. Humanity has been constantly panic-stricken and distressed by the sufferings and destruction of life through epidemics and epizootics. The ancients found themselves helpless and considered these outbreaks as evidence of divine wrath or caused by the 'evil eye'. They could take no active measures to combat them, and had to be content with offering tributes to various deities. However, through trial and error and by casual observation on animals in bad health, the ancient medicine man stumbled on many an antidote or nostrum. The monkey trying to stop with its paws the flow of blood from a wound taught him about blood coagulation; bears eating oakum leaves to cure stomach ache, stags using leaves for curing wounds,—such natural observations helped the early experimentalist find out the medicinal properties of herbs and plants, and to apply them to human beings and domestic livestock. The idea that life is a continuous process, and flesh, of man or beast alike, is subject to certain common laws, and suffers similar tribulations finds expression in the following lines written by Solomon, the wise, some 100 years before the birth of Christ : "For that which befalleth the sons of man befalleth beasts, even one thing befalleth them, as the one dieth, so dieth the other; yea, they have all one breath............".

THE UNITY OF HEALING SCIENCE

It is well to recall that the medicine of man and animal was born, almost contemporaneously, of the common parentage of credulity and

empiricism. The survey of the development and progress of healing science from early beginnings of trials and errors, through different stages up to date, reveals that the pioneers in all ages had apprbached the problem of diseases of the human race or of animal species more or less as single composite study. In the Vedic ages, animal medicine marched hand in hand with human medicine and both were included under Ayurveda, the science of life. In later periods also, all pioneer work, for instance by Leeuwenhoek on microscopy, identification of protozoa and bacteria, etc., or by Pasteur or Koch on bacteriology and immunology or Koch's postulates or Lister's work on antisepsis and advances in other epochs, have been applicable equally to man and animals, thus bringing out constantly the essential unity of the healiig science. It is fortunate that in the understanding of the factors determining health, the disease processes in man and animals have often thrown cross lights, and suggested analogies and have been mutually elucidatory. The understanding of a pathological condition in one species has been made possible only through the study of a similar condition in another species of animal. Whether the medical or the veterinary side has benefitted to a greater extent in this alliance of long standing is immaterial. Suffice it to note and remember that research and experimentations upon animals have provided the very basis of modern human medicine in therapeutics, immunology, dietetics, etc., and the contribution to human welfare by animals and animal studies has been of far-reaching consequences and very striking indeed. Sera and vaccines have been made from animals, and animal gland products such as pepsin, insulin, pituitarin, sex hormones, etc., are of constant use and of great value in human therapeutics. The study and understanding of animal diseases has also been of great public health importance as examples of communicable diseases, like glanders, rabies, brucellosis, tuberculosis, etc., are many. Veterinary researches have been essential in the elaboration of efficient public health measures.

This close association of human and veteriiary medicine is represented in a practical way in Great Britain in Medical Research Councils, in the Royal Society of Medicine, as well as in the British Medical Association, where veterinarians take active part in developing the subject of comparative medicine. In Universities like Cambridge, Liverpool, classes for medical and veterinary students are held jointly up to certain stages, while in the London University, the Professor of Physiology is the Head of the Department of Physiology in the Royal Veterinary College also. In the London School of Tropical Medicine and in Manchester University the diploma in bacteriology is being awarded to both medical and veterinary research workers. In the Pasteur Institute of Paris medical and veterinary researches are conducted side by side.

Turning to our country, not only were the first two Directors, Dr. A. Lingard and Sir Leonard Rogers, of the Imperial Bacteriological Laboratory, as the Indian Veterinary Research Institute at Mukteswar-Kumaun

and Izatnagar was called at first, medical scientists, but several other medical men have made outstanding contributions to Veterinary Research without going out of their way. It may be interesting to recall here that in 1899 a Committee consisting of Heads of Medical and Veterinary Services was appointed by the Home Department of the Government of India, and this Committee recommended the establishment of a Central Medical Research Laboratory also at Mukteswar, in conjunction with the Veterinary Bacteriological Laboratory already established there some six years ago. While the essential kinship between the two sciences had thus been recognised in India even from the earliest times, it is surprising the two branches have not functioned closer together to mutual advantage, as in other countries. The Indian Science Congress and the National Institute of Science have no doubt arranged to bring the two sister sciences together, but even here the objective has not been actively pursued with any degree of continuity. There are clear signs, however, that the specialised agencies of the United Nations have taken the initiative to develop the collaborative efforts on these common problems. For instance, recently a W.H.O./F.A.O. joint panel has recommended the opening in Mukteswar of a brucellosis centre to develop research and training and in the co-ordination of field and laboratory procedures used in brucellosis. Similarly, a scheme for the control of rabies in animals and human beings is being sponsored at Izatnagar. These new projects are now being considered by the Government of India. Such collaborative efforts to benefit the researches in human and veterinary medicine must multiply and the Indian Council of Medical Research will no doubt make this possible. While the immediate concern of medical science is the prevention and cure of disease in man and the building up of public health, the objective of veterinary science is also the safeguarding of the health of the community by the elimination of animal diseases and by the provision of dairy products and other foodstuffs of animal origin essential for the health and stamina of the people. Campaigns of disease prevention such as against malaria, tuberculosis, etc., are necessary but sufficient quantities of highly nutritive foods, e.g., milk and eggs, must be provided to improve the health, development and resistance to disease of the population before the full benefits of these preventive campaigns can be derived. Improvement of livestock is thus of fundamental importance to medical science as well.

ANIMAL HUSBANDRY—KEYSTONE OF INDIAN ECONOMY

Animal husbandry has been a much neglected art and science in India and is generally subordinated to the needs of agriculture rather than be allowed scope for development on its own right according to its intrinsic qualities. There has therefore been no occasion for the livestock industry to prove its highest potentialities on stabilising India's economy, and of making all the difference to the life and happiness of its millions of struggling cultivators. Sir A. V. Hill has rightly pointed out that the

neglect of the livestock forms the weakest link in our agricultural economy and grow more food campaigns. The fundamental role played by livestock, and particularly cattle, in the life and prosperity of our people is not appreciated. Until the full statistical data have been collected and marshalled, it will not be possible to enlist effective public interest, and to gain the right emphasis on livestock development in our plans of national rehabilitation.

India possesses over 150 million heads of cattle, more than one-fourth the world's total cattle population. In addition, she has 43 million buffaloes, 1½ million horses and ponies, 87 million sheep and goats, 4 million pigs and 73.7 million poultry of all kinds, 1 million donkeys and over ½ million camels. By providing transport for agricultural produce, it is estimated that cattle contribute annually approximately 300 crores of rupees. This sum is obtained by calculating the cost of cartage at the rate of one anna per rupee worth of agricultural products. The equivalent of cattle labour used for ploughing operations works out to be Rs. 1,000 crores. This is based on the fact that a pair of bullocks can plough 10 acres of land and the yearly cost of their maintenance is Rs. 450/-. The cost of ploughing 1 acre is thus Rs. 45/-, so that the cost for 230 million acres of net area sown in the Indian Union is over Rs. 1,000 crores. If we add to this Rs. 200 crores as the economic value of horse and camel transport, the total contribution from animal labour becomes Rs. 1 500 crores. India produces over 480 million maunds of milk per year, of which only 36% is consumed as fluid milk and the rest is converted into ghee or other milk products due to transport and storage difficulties. The price of this amount of milk and milk bye-products may be conservatively estimated at Rs. 750 crores. The amount of meat consumed in India is about 216 lakh maunds and its value may be put down at 130 crores of rupees. The number of eggs produced is about 200 crores, so that they also bring about Rs. 40 crores annually. Each year 583 lakhs of hides and skins are produced in our country whose value is over Rs. 40 crores. The annual production of wool is worth about Rs. 3 crores. Our cattle produce about 1,000 million tons of dung per annum, nearlf 67% of which is burnt as fuel whereas the rest is generally used as manure. Assuming a value of even Rs. 10/- per ton, the total economic value from this source is Rs. 1,000 crores. All these figures when added up, put the annual direct contribution from our livestock to be about Rs. 3,500 crores. This figure may be noted and compared to the income from certain industrial and agricultural commodities which loom so large in the popular mind. The iron and steel industry had a net annual earning of Rs. 58 crores in 1949-50, while for the same period cotton textiles and yarn were valued at Rs. 150 crores, jute at Rs. 78.2 crores and sugar at Rs. 54.5 crores. The annual coal production is of the order of 3 million tons, valued at Rs. 500 crores. It is not my aim to slight the vital role played by these commodities in the economic life of a nation and these must receive their fullest share of support to effect the much needed rapid

industrialisation of the country. What is emphasised here is that livestock and their products form the most valuable and basic national wealth of our country in particular and this represents a fairly large portion of the world's total resources of animals and animal products, the development of which is vital to the interest of human welfare.

The figure of Rs. 3,500 crores given above indicates only the direct annual return from our livestock population, but the indirect profits, much of which is at present potential should not be lost sight of. From time immemorial, man and cow in India have become by long association inseparable entities. Cattle till our land, thrash our grain, invigorate our fields by supplying manure and carry the agricultural products from the field to our homes and bazars. Cattle have to subsist only on the bye-products of human food, namely, straws, bran and oil cakes, and in return for this the cow yields milk which is so vital for human beings, especially for growing children. Other livestock provide meat and eggs—quality food which are essential for our proper nutrition. An unbalanced diet consisting mostly of cereals may appease the hunger but it is a well-known fact that it can not produce peoples of stamina and efficiency. Physicians the world over are agreed that psychological traits, such as, laziness, inability to concentrate the mind, a constant feeling of malaise are caused by a diet lacking in animal proteins. All these go to prove that the welfare of our nation, and in fact of every nation, is correlated vitally with the welfare of the domestic livestock and one cannot do without the other. During the evolutionary process of industrialisation in our country, however, this integration between man and animal has been lost sight of. The urgency to produce more of the bulky food to appease the hunger of the growing population, or the stepping up of the production of such agricultural commodities like tea, cotton, jute to earn ready cash has resulted in the neglect of our cattle. Such land as were previously kept apart for grazing has been brought under the tillage, and the intensive cultivation of cereals and cash crops has resulted in the decline of the fertility of the soil. Cattle have been made to do more work without enough food, and this has led to the diminution in their productive capacity. This vicious circle has now proceeded so far that "quality" has disappeared from the Indian diet. The loss of vigour in the Indian cattle and other livestock coupled with bad management has made them easier prey to the ravages of epizootic diseases, so that the present picture is that of puny, feeble creatures low in all capacities for work or milk or meat production.

LIVESTOCK INDUSTRY IN INDIA IS UNDEVELOPED

It is high time, therefore, that our attention is focussed on the improvement of our livestock, and especially cattle. Even from the present-day degenerate cattle we are getting a value amounting to about Rs. 3,500 crores every year. This figure, though vast, shows only one side of the

picture. The earning per head of the cattle works out to be Rs. 120/- per annum. With proper feeds and management, this figure can be improved to Rs. 150/- as it is known that by supplying proper feed the milk yield can be improved by 50% and the working capacity by 20%. The minimum cost of adequate maintenance charge per head of cattle is however Rs. 150/- so that animal husbandry in its present state does not appear to be a paying concern in our country. It is, however, stressed once again that the above figure is that of an undeveloped industry where raw materials are the animals which have been rendered degenerate through centuries of neglect.

The economic prosperity of several countries have been based on their livestock industry. New Zealand is a small country, roughly the size of Great Britain, but she is the largest producer of dairy products and possesses sheep by the millions. Her two million people posses 16 sheep to every man, woman and child. All her wealth and high standard of living originate from this great pastoral advancement. Similarly, Australia's greatest industry is her wool and her greatest prosperity depends on wool prices, which brought her during 1950-51 £.637 million. Australia made its humble beginning only in 1790. When Captain Cook landed at Botany Bay in 1788 there was not a single sheep in Australia. Even taking the case of underdeveloped countries, South-West Africa earned last year £.6 million by her Persian lambs' industry. There is no reason why India cannot do even better with her enormous natural resources of this underdeveloped industry which still makes an annual contribution to the tune of Rs. 3,500 crores. Our cattle do not lack the genetic make-up for better production, and breeds of Indian cattle have proved their worth in U.S.A., Australia, East Africa, etc.

CATTLE POPULATION—NO SURPLUS

It has been argued by some economists, as well as by some foreign experts that the large cattle population in India is a great burden, and that the available land is not capable of maintaining both the human and animal population. This statement needs qualification. It is true that India possesses an appreciable proportion of less productive animals. There is certainly a strong case for replacing some of our cattle by better and more highly producing animals to ensure economic returns, but for a long time to come we shall require a large number of animals in this country. The total milk production, even if it were consumed wholly as fluid milk, would yield only 5 oz. daily per head of the human population. Modern concept of dietetics places the minimum need at 10 oz., preferably 16 oz. daily per person, so that until the time we have upgraded our milch animals to such an extent that there is a surplus of milk, we cannot think of diminution of the number. Besides, by improved feeding alone these animals are capable of giving better yield of milk. Again the net sown area in India at present is about 230 million acres. This area can be in-

creased to 300 million acres by reclaiming some of the cultivable waste land. If from these, 100 acres may be sown more than once through irrigation, the total available land, i.e., 400 million acres, will be sufficient for both the human and animal needs. In order to cultivate these lands, 60 million working animals are required, and India has got only 60 million bullocks. Thus, neither in the category of milch nor in working animals is there any real surplus. On the other hand, due to the ravages of epizootics, it appears more than likely that there is really a dearth of all class of producing animals—a fact which is supported by the phenomenal rise in the price of such categories of cattle.

Moreover, it may be stressed emphatically that if proper care is taken in the distribution of land and sowing practices, the yield of nutrients per acre of land may be substantially increased. It has been pointed out before that as a result of continuous non-rotational cultivation, the yield of grain per acre is very low in this country. This has been the experience in other countries also, but by a process of mixed farming, i.e., through the adoption of a grass-grain rotation, the yield of cereals has been improved quite considerably. In Illinois, it was found that when maize was grown continuously in the same land for 39 years, the yield per acre dropped from 41 bushels to 24 bushels. In comparison, 50 bushels of corn per acre was obtained in a three year rotation following clover. Moreover, in such a mixed farming we get in return for the grasses grown such valuable food products like milk, meat, etc.—products which go a long way to increase the vitality of our people. Thus, mixed farming which was the basis of agriculture in old India should be taken recourse to, if we are to improve our physical and economical status. Certain countries have allocated the major portion of the available land for the development of pastures and the growing of fodders for animals rather than for the growing of cereals for human beings, and this has been proved to be in their best interest.

ERADICATION OF DISEASES

In order to maintain the rhythm of intensive cultivation which is the crying need of our country, it is essential that our animals should be properly managed. Maintenance of health must depend on adequate feeding and eradication of diseases. The question of feeding has already been dealt with. Diseases not only the virulent epizootics, but helminthiasis, protozoan infections, etc., also sap the vitality of animals and produce stunted growths and degeneration.

I shall try to indicate the ravages that are caused by disease and the economic losses sustained thereby. Statistics are very meagre, but recurring losses are unmistakable. Science has provided us the tools by which these losses can be largely eliminated but what is needed now is a concerted effort to bring the laboratory experience to field practice. The control of snails in long stretches of low-lying areas will certainly save much valuable livestock from the serious depredations of liverflukes and

other trematodes, but these field operations must be carried out rationally on a large enough scale as in the campaigns directed against locusts and malaria.

The losses resulting from an outbreak of any epizootic disease are manifold. The net loss due to death can more easily be ascertained. Besides these, a much larger number of affected livestock are rendered immobile or useless for production purposes for a considerable period, and many of them may even after survival become useless burdens due to some permanent physiological damage like sterility. No statistics for such cases are yet available. Neither is it easy to calculate the loss due to impairment in working capacity, loss in milk, meat, egg or wool production by the affected animals. Recently, the Indian Council of Agricultural Research has arranged to compile the vital statistics of animals in the different States of the Indian Union, but only about 50% of the mortality is brought to the notice, while the percentage of affected animals covered by the monthly tables is still smaller. Even then, the reported losses due to the more important animal diseases for the year 1951 is given below and the figures speak for themselves: (1) Rinderpest—46 thousands; Haemorrhagic septicaemia—30 thousands; Blackquarter—18 thousands. The total annual mortality from infectious diseases alone is given to be a lakh, while the figure for those affected by these diseases is over 5 lakhs, of which more than 3½ lakhs suffer from Foot-and-Mouth disease. Allowing for the unreported cases, we can easily put down the number of deaths at the conservative figure of 2 lakhs and those affected at 20 lakhs. Assuming an average price of an animal at Rs. 150/- the annual loss due to death alone is 3 crores of rupees. If we add to this figure, the invisible losses in food growing and milk production caused by the absence of these animals, this figure may be many times more. The number of affected animals is about 1% of the total livestock population of India. It may be assumed that due to debility, the productive power of the diseased animals is reduced by 30%. In that case, the loss may be taken as 0.3% of the net earning from livestock or in other words about Rs. 12 crores. This figure also does not take into account the unknown number of animals which are rendered permanently unfit for any useful work. Summing up, we may deduce that epizootics alone are costing the country to the tune of Rs. 20 crores annually. Over and above this, a much larger number of animals suffer from various chronic diseases caused by protozoa and helminths. Such diseases also cause considerable debility and quite a large proportion of mortality as well. As no statistics are available for such cases, it is not possible to calculate the losses in rupees, annas and pies. However, as a concrete instance, it may be mentioned that a loss of Rs. 1½ crores is incurred annually through the depreciation in the value of hides by warble-fly infection alone.

CONTROL OF EPIZOOTICS

It may be of interest here to recount what has been done so far for

the control of epizootics. Considering the vast area of India, and its large number of species of livestock under different conditions of soil-climate complex, our country has only one Research Institute to investigate into the nature of prevailing diseases, and to give advanced training in field work, teaching and research. Students have been attracted from the neighbouring countries, and occasionally from long distances. The question of raising the standard of veterinary education and bringing about uniformity is engaging the attention of the Indian Council of Agricultural Education. The staff of this single Institute had never been adequate to cope with the problems of animal preservation and development. Though the Indian Veterinary Research Institute, founded in 1890, is the oldest research institution in the whole country and reflects the urgent necessity of that time for livestock preservation against the widely prevailing animal plagues, the question of the further development of that Institute in particular and Veterinary Science in India in general, had not received the motherly care and protection as their importance in the country's welfare demanded. However, even working under serious limitations, the veterinary scientists have been able to develop effective remedies for the protection of our livestock against most of the serious animal diseases prevailing in this country, and have undertaken studies on problems of animal nutrition, breeding and technology. In fact, there is more urgency now for further intensified work, and the lines of work which have yet to be undertaken and developed are many. No systematic researches have yet been undertaken in the promising field of the elaboration of cheap and efficacious treatment of animal diseases from the indigenous drug resources. In animal disease control work, the main object is to find out the means of *preventing* diseases. It is commercially unsound to cure diseased animals, as individual cures might cost more than the patient might be worth to the farmer. In fact, countries have ruthlessly killed all animals suspected of carrying contagious diseases in order to stamp out such maladies like rinderpest or foot-and-mouth disease. Hence prevention rather than cure is the basis of veterinary practice. This fact emphasises the justification for the origin and development of modern immunology in veterinary practices, and prolonged experience has shown this to be a definite advance on the indigenous Yunani or Ayurvedic medicines as far as the rapidly spreading contagious diseases are concerned. These systems have their merits and are valuable in certain chronic maladies, but it must be emphasised here that any haphazard attempt made to utilise these in the control of outbreaks of epizootic diseases such as rinderpest, foot-and-mouth disease is likely to result only in the wastage of efforts and resources. Therefore, a supply of reliable veterinary biologicals is essential for the needs of the country, and fairly large quantities of over twenty-five different products are produced at Izatnagar and other centres. An Expert Committee for the Standardisation of Veterinary Biologicals has been set up by Government of India, and two eminent medical men have been included in this Committee.

Further, it must be remembered that one has to treat animals in herd or *en masse*. It is necessary that all the useful animals should be protected by a vaccine which should give sound immunity for a long stretch of period. As the number of animals in the country is very great, the price of such biologics should be cheap as otherwise the cost of prevention will be beyond the means of the farmers or the Government. For example, after prolonged periods of research a reliable vaccine giving satisfactory long term immunity against foot-and-mouth disease has been evolved at Mukteswar, but the cost of a single dose is about Rs. 5/-. When the number of cattle are considered, it may be seen that to immunise the 200 million heads will cost Rs. 100 crores as the price of the vaccine alone. If we take into consideration the expenses for maintaining the personnel for collecting and vaccinating these large heads of animals, the total expenses easily mount up to another Rs. 100 crores or more. It is evident that expense on such a scale will be beyond the capacity of the country for some years to come. Again, there is a comparatively cheap vaccine against haemorrhagic septicaemia which costs only annas two per dose. Unfortunately, however, the immunity that results from this treatment lasts only for three months, so that it is necessary to vaccinate the susceptible animals at least once every year. The huge recurring cost prohibits its use on a mass scale and only organised large farms where valuable animals are maintained can afford to undertake such treatments. Hence our aim has been the production of cheaper and better vaccines and with the technical assistance of the F.A.O. arrangements have been made to modernise production procedures and to instal latest equipments at the Central Institute, and at some of the major State Centres. How continuous research may help towards this is exemplified in the story of the control of rinderpest.

CONTROL OF RINDERPEST

Rinderpest is a world problem. It had always been and in fact still continues to be the most important contagious animal disease. It attacks all ruminants and the mortality rate is very large. In the 1860's, rinderpest was ravaging the country-side on a wide scale and was responsible for the loss of nearly ten lakhs of cattle every year. In large areas of the country, agricultural operations came to a dead stop. The Government of the time established the Imperial Bacteriological Laboratory to find a remedy against this fell disease and Robert Koch was invited to Mukteswar to advise. Within nine years of the establishment of the Institute, an anti-rinderpest serum was evolved. This biologic at first was rather costly, and could render the animals immune for short periods only, so that it could used as a temporary protective only in the actual sites of outbreaks. Further years of research saw the lowering in the cost of production so that the price of one dose came down to one anna only. However, the short period of immunity made this treatment available mostly for use of costly animals in the military and civil dairy

farms. In 1927, the virus was fixed in goats and the attenuated vaccine made from goat spleen was found to render life-long immunity in the treated cattle. The price of the vaccine was also cheap, being Re. 1|2|- for 100 doses. This newer tool helped in carrying out large-scale immunisation in all parts of the country, and thereby the deaths from rinderpest have been brought down by 90%. However, this vaccine, which costs about 2.5 pies per animal, has some drawbacks, as it produces high reaction and mortality in buffaloes where it has therefore to be used in conjunction with anti-serum, which increases the cost. These defects have prevented the wholesale immunisation of the animals in India. Recently we have evolved a still cheaper lapinised vaccine, which produces practically no reaction in the immunised animal and yet renders solid immunity. The time has therefore come when a concerted attempt may be made to eradicate the disease from India.

ERADICATION OF RINDERPEST

One of the chief handicaps in undertaking any scheme of animal disease eradication has been the paucity of men and finances—compared with the vastness of the problems. It is a sad fact that veterinary profession in India has failed so far to attract a large number of students. Economic consideration is the chief reason for this apparent *boycott,* as livestock development has until recent times received only scant attention. The annual budget for veterinary and livestock departments in all the provinces of British India for many years had never exceeded 50 lakhs. This works out to be a little over a quarter of a pie per head of animals compared with 95 in United Kingdom and 248 in Switzerland. Fortunately, the public and Governmental interest in animal husbandry has recently been on the increase. More Veterinary Colleges have been opened and quite a number of schemes for livestock improvement is being undertaken. It is in this context that I took the opportunity to present a ten-year plan for the eradication of rinderpest in India. This plan has been accepted in principle by the Government of India and has been mentioned in the Five Year Plan. The F.A.O. has also agreed to help this plan by supplying expert personnel as well as through procurement of the machinery necessary for the mass scale manufacture of the vaccine.

When the well-being and efficiency of the large number of affected animals and through them those of their owners are taken into account, the imperative need for such eradicatory measures becomes all too evident. With the experience gathered from this scheme and through continuous research, the path may be opened to the future veterinarians to make India a safe country for all types of domestic animals—a condition that is essential if we are to convert our country into the "Stud Farm of the East".

RANIKHET DISEASE

I may also mention another achievement of the Institute for which we may be execused reasonable pride. Organised poultry farming in India

had always been a hazardous attempt, as the owner used to find one morning that his whole flock has been wiped out through the outbreak of the Ranikhet disease. A vaccine from incubated eggs has fairly recently been evolved, which involves a cost of only 0.5 pies per bird. Extensive field operation in India and abroad has proved the efficacy and usefulness of this vaccine. Poultry farming in India has now been made a safe venture. This has not only paved the path for the establishment of a new industry, but indirectly it has provided the nation with the means by which quality foods like meat and eggs can be produced economically in large amounts by the use of electrically operated mammoth incubators. The prospect of an egg a day for the people of India has been made a reality, so that the deficiency of milk proteins which takes long periods to remove can be made up readily. I leave it to my medical friends to think about the probable impact of this on national health and wellbeing.

I have dwelt at great length on the importance of animal husbandry in the economy of India in the context of the slogan "Produce or Perish". All that I want to stress is that livestock plays a key role in the problems of food production engaging the mind of all thoughtful persons. In order to step up the agricultural production of our country we need sturdy, healthy animals. In fact, unlike other countries agriculture is ancillary to the livestock in this country. The prevention of animal diseases is not only a direct approach towards the smooth functioning of agricultural operations but is also essential for maintaining the morale of our agriculturists, who had often in the past been frustrated in their efforts through the sudden outbreak of diseases. In fact, the suddenness of the epizootic diseases and the mortality rate caused thereby had, in no small measure, been responsible for the degeneration of our cattle. Once it is ensured that an animal and its offspring are going to live for reasonable periods, the path will be opened for upgrading the future generations so that better productive power may be developed. Improvement of large animals is a time consuming process, and extreme care is required in choosing the particular breeds which are likely to be the best adapted for different regions. A climatological laboratory is proposed to be set up for testing out the potentialities of each breed under different environmental factors. The Key Village schemes which have recently been inaugurated in India are an attempt to bring about the prosperity of the rural population through multipurpose activities in which livestock preservation and development will play a prominent role. For the whole of India, over 200 such schemes however cover very little ground.

There are many calls on our budgets, and we cannot expect to start everything all at once. In other countries, private individuals and bodies have always played a large part in livestock improvement. In Great Britain, Animal Health Trust was started a few years ago as a private body financed entirely by philanthropists. This Trust endows much larger amounts for research and training than has been possible by the Government of the country. India possesses many large-hearted philanthropists

and may we not hope they will take more lively interest in livestock improvement work, if only we can draw their attention to the vital necessity for such endeavours in India.

One more theme and then I conclude this address. Within our limited means we veterinarians have managed to achieve some success in the laboratory, but very much more yet remains to be done. In this effort, I feel that our brother scientists can help us a great deal. In these days, no science stands alone. The task of national regeneration is many-sided and colossal, having for its objective the removal of poverty, dirt, disease and ignorance. The present shortages and deficiencies menacing us have to be removed, and the solution of many of India's ills requires a revision of the conventional lines of attack. Projects of public welfare can have no real significance to a people in a subhuman level of nutritional existence. To this end, the resources of all branches of science should be directed in a co-ordinated manner. If the enormous advances made in the physical sciences can be utilised even in a small measure towards the investigation of veterinary problems, I am sure that will reap great mutual benefit on all sides. Indications are that the resources of X-ray, ultra-violet radiations, ultrasonics, electron microscopy, isotope tracers, antibiotics, etc., if applied to animal physiology and pathology are sure to result in discoveries of great value. Similarly, the greatest stimulus that can be given to the farmer for renewed interest in livestock is to show him that there is money in livestock farming and satisfactory returns from internal and external trade in livestock are likely to follow to improve his economic status. Better utilisation of the farmyard manure, eradication of such pests like ticks, flies and other insects and hygienic management, which can be devised through biological sciences, will help him in this effort. Moreover, he must be assured of speedy despatch of his output in a wholesome form to the consumers, so that maximum monetary gains can be obtained. In these, the resources of the engineering science in providing technical equipment, better transport and refrigeration facilities will be essential. It is in meetings like these of the Indian Science Congress where representatives of all branches of science meet, and can take counsel together to evolve a common plan for the scientific development of our animal resources—a plan which will not only primarily help our rural population but in the long run is sure to increase the prosperity and good health of the entire population.

40th INDIAN SCIENCE CONGRESS, LUCKNOW, 1953

SECTION OF AGRICULTURAL SCIENCE

PRESIDENT : N. PARTHASARATHY, Ph.D., F.N.I.

Presidential Address

GENETICS AND CROP IMPROVEMENT

INTRODUCTION

In the presidential address before this section Mr. Ramiah (1941) has given a general survey of plant breeding and genetical work in India referring to two important crops, rice and cotton with which he was familiar. During the last 10 years and in fact nearly 50 years after the rediscovery of Mendelian Laws, genetics has made vast strides of advancement out of all proportions to its recent origin. We have in the place of an abstract factor, or gene, as conceived by Johannsen, a material particle, a unit with its own inherent property which is dependent on the linear correspondence of its partners and the nucleus as a whole. Attempts to understand the nature of the gene and the mechanism of its action have resulted in genetics impinging upon all sciences as it deals with the fundamental unit of life. The nature of the action of gene is being studied in the lowest types of life like *Neurospora* and these studies are forming part of a new discipline, namely, bio-chemical genetics and the bio-chemical geneticist is dealing with the gene as the largest of the molecules he is conversant with. Modern genetics, therefore, is an unification of all the sciences and its ramifications extend to chemistry, physics, physical chemistry, breeding, etc. The synthesis has made plant and animal sciences into one. Recent developments in the sciences of physics, chemistry and mathematics have made remarkable contributions towards the unification of these sciences with genetics and towards a better understanding of the nature of gene. This knowledge has placed in the hands of geneticists, tools with an accuracy and precision hitherto unknown. Techniques resulting from advances in enzymology, the micro-manipulator, absorption spectrometry and the electron microscope are but a few which are made use of by the present day geneticist. As a consequence, the tremendous complexity of the gene action is getting to be unravelled although not fully. If the *Drosophila* work is recognised as responsible for the unification of genetics and cytology, the study of the biochemical genetics of micro-organisms like *Neurospora* late in this century can be said to have unified chemistry and genetics.

The usefulness of the study of genetics to man is very great. In addition to the improvement of crops it is expected to play or is playing an important part in the improvement of society. X-rays and chemicals can break up chromosomes. Nuclei can be combined, separated or modified. In short "we can compress a millennium of variation within a few minutes". Species that hitherto did not cross with each other can be crossed; hybrids that were sterile can be made fertile and innumerable heritable changes can

be introduced. Therefore these techniques strengthen plant and animal breeding. Domesticated plants and animals have been standardized for the use of man. Resistance to diseases and insect pests have been built up by utilising related species from different sources.

Thus, the importance of the study of fundamental genetics is obvious. I propose to give in this address the important contributions made by genetics, their application towards crop improvement and also indicate the necessity of the study of this subject in India where it is regrettable to note that so far no serious attempt has been made to place this science on a footing equal to its importance.

Agriculture is essentially a product of domestication. This domestication started in pre-historic times and progress was made in the selection and growing of important food plants. Darwin as a student of evolution studied variation amongst plants and animals under domestication and attempted to get a kind a magnified idea of evolution in nature. According to him variation was dependant on hybridization, selection and in-breeding. Two epoch making discoveries made after Darwin's period have thrown more light on the variation on which evolution depends. They are first, discovery of the principles of inheritance by Mendel and secondly, mathematical application of these principles for a clearer understanding of evolution. The importance of these studies in agriculture lies in the fact that they enable us to find out how genetic agents of evolution act and interact in an environmental frame work quite different from that occurring in nature. Cultivated plants have been found to have their origin about 10,000 years ago. It might be possible to get a correct estimate of the date of origin by testing the radio-activity of the fossil remains. From the point of view of evolution, this period is very brief and it is remarkable to consider that the host of varieties of cultivated plants of today are not a result of gradual evolution but are due to the conscious effort of man. He has selected them and grown them in the man-made environments. Natural vegetation has been removed; chemical and biological properties of the soil has been changed, plants were protected from disease and pests and by providing irrigation, climate has been changed to a great extent and competition with other species reduced to a nimimum. Natually the study of the evolutionary agents under this changed environments would give important clues on the impact of genetics in agriculture.

The principal genetical agents which are connected with Agriculture are 1) mutation 2) hybridization and 3) selection. Apart from these, there are others like isolating mechanisms and changes in environments which operate through these agents and all these are at work in Nature and there is yet another factor under conditions of domestication i.e., the human fator. Man has to a remarkable extent accentuated or exaggerated the action of these agents. Man has created new niches to some of the favoured species of plant kingdom because of their usefulness and as such their evolution followed new paths. Most of these species were originally very poor competitors under natural condtions and would have become extinct had it not been for man's intervention, sugarcane being one such example. It may be seen that many of the cultivated plants are not known in the wild state. The common wheat is an example. The species which probably had a very restricted range in Central Asia, now occupies about 400 million acres of the earth's surface. It is therefore a fascinating study to consider how the agents of evolution have worked to adapt the cultivated plants to the new niches that man has created for them and how the knowledge of

the genetic forces that are in operation in evolution help us to improve these plants than what they are. These problems are, therefore, basic to crop improvement.

Mutations

Both in nature and under domestication mutations are to be considered as the building blocks of evolution. The immediate causes of variation are due to segregation and recombination. There is no doubt that the ultimate source is mutation. Does mutation affect the cultivated plants in the same way as they do in wild populations? Are artificially induced mutations economically useful? These are very relevant questions which pertain to crop improvement. The cultivated plants represent a special category and one of the remarkable features as compared to wild plants is the obtaining of greater number of mutations in the cultivated plants. This is due to (i) the increase in size of population resulting from large scale cultivation and (ii) the well adapted nature of the wild plants which have a low mutation rate. Agriculture can be said to have exploited mutations to a great extent than Nature and a proper study of the Nature and control of mutation processes is essential for further exploitation. On the one extreme, the genetic effects of a mutation are of such magnitude that the death of an organism is ensured. Considered from the point of view of improvement of domesticated plants, these mutants called lethal mutants are of little significance. To this group can also be added such of those mutations which affect the reproductory system in such a way that either complete or partial sterility results. However, some of these mutations as male sterility has been put to use in the breeding technique.

Special importance is attached to mutations which affect several parts of the organism but without affecting the fertility of the individual. Many of the single gene differences in wild and domesticated populations are of this category. The effects in some are so distinct that the mutant plants are being designated as a separate species. The *sphaerococcum* gene of wheat *T. vulgare*, is an example. The breeder looks forward in related species of cultivated plants for such mutants which are likely to benefit the crop plants.

It is often the experience of the plant breeder that the character differences between races and species are controlled by multiple factors which are due to the occurrence of several mutations. In addition to these multiple factors there is also found a system of modifying genes. These small mutations are most important in building up the differences between the species. Recent study of continuous variation has led to its analyisis and to the classi- of polymeric genes with recognisable phenotypic effects and polygenic genes where the phenotypic effects are not so recognisable. The role of small mutations in the expression of these gene systems is important as many of the characters of economic importance exhibit variation of the continuous type. Most of the mutations either spontaneous or artificially produced through the agency of x-rays, etc., produce phenotypes which are less viable, abnormal or weak. This is to be expected as the genic complement of any species is a complex system whch is well balanced with the environment. Any change upsets this balance and occasionally useful mutants could probably be isolated if these are exposed to a new environment. An important conclusion of far reaching possibilities has been drawn from the work of Dobzhansky and Spassky (1947). They have reported that a genotype not favoured in a normal environment due to reduced

developmental rate, reduced fertility, etc., becomes established in a different environment due to favourable mutations and gene re-combinations and reverse is the case with a wild balanced genotype.

It has been observed that the rate of spontaneous mutation is very low in nature (about 1×10^{-6}). One of the remarkable discoveries of last decade is the finding of Muller that the rate of mutation can be considerably increased by artificial agencies like high energy radiations. The point has also been emphasised by Dobzhansky (1941) that the rate of spontaneous mutation itself varies from one race to another in the same species and from one locus to another in the same individual. Mutations therefore can themselves be said to be under genic control and the increase in the mutability of one gene through the effects of other genes with which it is associated has beennoticed in maize and in cotton. It would therefore appear that mutation rates are themselves controlled by natural selection. Since most of the mutations are deleterious in their effect, natural selection will tend to lower the rate of mutations in the well adapted and established species. An old pure line and two new strains of barley, relatively recent products of hybridization were taken up for study by Gustafsson (1947). The latter group showed higher frequencies of x-ray induced morphological mutations than than the former. It would appear that the high stability has been broken up in the newer varieties. Various attempts have been made with some success to induce mutations in crop plants. In addition to a number of deleterious mutations, a small group of exceedingly important induced mutations have been obtained. How well these few mutants can be harnessed in crop improvement is illustrated by the work of Gustafsson (1947). In barley in which extensive work with-x-ray induced mutations have been carried, physiological mutants with stronger straw, higher grain weight and early maturity have been put under trial for several seasons and the superiority of some in the above mentioned characters and also in yield has been been well established. Similar barley mutants showing increased yield which in some cases show an increase of 27.8% over controls have been reported by Kuckuck and Mudra (1950). Amongst other crops in which profitable mutants have been isolated is the flax mutant (Levan, 1945) which has a superior fibre yield and a good seed yield. In rice, Ramiah and Parthasarathy (1938) isolated a mutant which proved to be of economic value. This mutant was slightly shorter in stature with a larger number of tillers than the original parent material and is useful in rich soils where the problem of lodging is serious.

An interesting observation made by Gustafsson and MacKey (1948) is the phenomenon of heterosis exhibited by X-ray plants especially when the irradiation dosages are low and medium. Heterosis is attributed to the induction of recessive and lethal mutants. The results are comparable with the findings of Jones (1945) that spontaneous deleterious mutations in the heterozygous state increase the yield of in-breds. It has also been observed that in a heterozygous condition it is the lethal mutations which cause heterosis rather than vital mutations. When it is remembered that natural selection acts more on recombinations than on mutations, it is hoped that the induced mutants would prove more vauable as material for further breeding by recombination. In a new genetical environment even mutants with bad effects might show a favourable reaction after recombination (Muntzing, 1951). So the appearance of numerous unfavourable mutations need not discourage the breeder as the potentialities of these mutations for crop improvemet has been indicated above.

Another allied field of work with far reaching importance is the use of chemicals in the production of mutations. These studies recently standardidised by Auerbach, Robson and Carr (1947) in the use of mustard gas have opened up a new approach to problems of cytogenetics and cyto-chemistry. The work on chemical mutagenesis is still in its infancy. But the results already obtained give us a preview of the possibilities. Fundamental problems like the nature of the mutation process and the nature of the gene to vital problems like the cancer fall within its scope. As only a small fraction of one percent of the mutations occurring in natural populations can be accounted for by radiations present in nature, it is reasonable to suppose that spontaneous mutations are probably also caused by the by-products of the metabolism within the cell. Auerbach (1949) supports this view by showing the mutagenecity of mustard oil and its presence in *Brassica*. On the other hand, Demerec (1948) has demonstrated the mutagenecity of a number of chemicals, most of them found in plants. The high stablity shown by plant species in spite of the widespread mutagenic property of their products has been attributed by him to the fact that the chemicals for the induction of mutations are required in a concentration which is highly toxic to the organism and only a few that are exposed to such concentration can survive.

But a completely new field of vast practical and theoretical interest has been opened up by the discovery of specific mutagens. The specificity can be recognised at two levels. Specificity may be seen in the effects like gene mutation *versus* re-arrangement, heterochromatic *versus* euchromatic mutations. It might be seen on the individual genes or group of genes. The recent results obtained by Ford (1948) and Deufel (1952) with *Vicia faba* that heterochromatic regions are preferentially attacked has assumed a great significance, for it is conceded that the genetical control of growth is mainly dependent on heterochromatic genes. It may be sometime before chemical mutagenesis makes such progress as to make methods by which specific desirable mutations can be obtained by the plant breeder. From the progress of the work such an expectation is not beyond possibilities.

Polyploidy

The phenomenon of polyploidy is one of the most widespread and distinctive features of higher plants. In the few plant species which have been throughly studied, polyploidy has been found to play an important role in speciation. The publications of observations related to induced polyploids are numerous. The role of induced polyploidy in plant breeding can be considered at two levels (i) the use of autopolyploids of crop plants in crop improvement and (ii) the use of artificial allopolyploids (a) to evolve new crops (b) to synthesise existing crop plants from parental species and (c) to overcome interspecific sterility so often encountered in breeding investigations. Comprehensive reviews of these have been made by many investigators.

The results obtained in the use of autopolyploids have not been often successful. In crops grown for the yield of vegetative parts like tubers, roots, etc., the autopolyploids by virtue of their increased size were found to be of immediate use in agriculture. Instances can be cited from the work in sugarbeets and radish. With reference to autotetraploids of crops grown for grain yield it can be said that complete success has not been achieved so far. The reason for this failure is the handicap of seed sterility. The reasons for this seed sterility in autotetraploids are far from being well understood. The

sterility has variously been attributed to cytological. genetical, physiological or embryological causes. It was at first supposed that the formation of multivalents resulting in gametes with unbalanced chromosome number caused the sterility in autopolyploids. It was also further assumed that chromosome length which is related with multivalent frequency also indirectly controls the sterility.. Subsequent investigations, however, proved that seed sterility in autopolyploid is not correlated with multivalent frequency. Most of the studies on the meiosis of autotetraploids have been made with PMC and the meiosis in EMC has been assumed to follow similar trends. That this need not always be so, has been shown by Einset (1947) in *Lactuca* where the breakdown of meiosis in 20 per cent of the ovules was noticed, while meiosis in PMC was found to be normal. Even considering these absormalities to be responsible for seed sterility, it cannot be denied that only a small part of the sterility is accounted for. Randolph (1941) has explained that seed sterility might be due to the action of genes. The hypothesis of genes conditioning fertility has been put forward by many investigators. It is presumed that the genetically controlled physiological factors of an unknown nature but not related to meiotic irregularities are responsible for the sterility of the autotetraploids. Another hypothesis that the sterility is controlled by genes but these genes are small and cumulative in effect and unrecognisable individually has been proposed by Parthasarathy and Rajan (1952). This is supported by indirect evidence from the results of breeding experiments in the autotetraploids of *Brassica.* That the mechanism of the failure of the seed to set is embryological in nature has been shown by Hakansson and Ellerstorm (1951) in autotetraploid rye and Rajan and Ahuja (1952) in autotetraploids of *Brassica.* In rye, the sterility is mainly due to the non-fertilization of normal embryosacs and abnormalities in the development and differentiation of the endosperm. In *Brassica,* however the abnormalities in the formation of the embryo sac account for the major part of seed steility. Scholsser (1944) attributes the cause of sterility as due to lack of balance between nuclear genes in a doubled condition and plasmagenes in the cytoplasm which are not so doubled. The exact nature of of the causes, therefore, appears to be very obscure and the complexity of the problem has defied solution so far. While the causes for the sterility remain obscure, attempts have been made to improve the fertility of autotetraploids by various workers These attempts are being met with varying degrees of success as in rye (Muntzing, [1951] and in *Brassica* (Parthasarathy and Rajan, 1952) where the sterility has been overcome to a great extent. In general it appears that cross pollinated plants lend themselves better for improvement of fertility than the self pollinated crops. Seed yield in the autotetraploid as in any other plant is controlled by a set of characters of which seed fertility is one. Since the use of autopolyploid in improving grain crops is in the increased seed size, improvement of other characters besides fertility and seed size which contribute towards the increased yield should also receive consideration. Towards this end, characters like branching, number of flowers, seed weight, and fruit size have been studied in the tetraploids to find out their possibilities for increasing yield. From a comparative study of the tetraploids with their corresponding diploids for a number of characters it was found that no rule of general applicability could be recognised. Different characters in the same tetraploid show a shift towards positive and negative directions to different degrees as compared to the diploid. Further it was noticed that the behaviour of tetraploids from different types or varieties or pure breeding lines within the species was very variable when compared to their performance at the diploid level. Therefore no prediction of their performance could be made from a knowledge

of the behaviour of parent diploids. From this it would appear that different genotypes even within the species respond differently to polyploidy and this is of considerable significance inpolyploidy breeding. The genetical basis of such a differetial response of the genotype to chromosome doubling appears to be similar to that of the "efficiency maximum" of genes shown by Lawrence and Scott-Moncrieff (1935). Similarly Levan (1951) finds that tetraploids from those diploids of linseed which have been already subjected to selection for stem length, show less favourable response for chromosome doubling than those of unselected diploids. The outcome of all these studies related to autoploypIoids appears to be that induced autoploypIoidy can be profitably used by the plan breeder in crops grown for the yield of their vegetative yields, for size or flowers, etc., and it appears that further investigations are necessary in the utilisation of autopolyploids in plant breeding especially in crops in which seed yield is of high importance.

The position regarding induced allopolyploidy is quite different. Many of our important crop plants are natural allopolyploids like wheat, tobacco, cotton, etc. One of the most fruitful results of the colchine technique is the demonstration by artificial synthesis, the parentage of many of our crop plants. These natural allopoiyploids are the results of a series of rare accidents. Equipped with the knowledge of the genetic make up and inter-relationship between the ancestral species it should be possible for the plant breeder to build up alloploids better suited to his requirements in a very short time. Again induced amphidiploidy is important to plant-breeding in two ways: (1) it can be used in transfering across a barrier of interspecific sterility desirable character controlled by a single gene, as for instance, the mosaic resistance in tobacco and resistance to phylloidy in *Sesamum orientale*. This method is of great significance as it makes available to the plant breeder a hitherto untapped source of useful genes from wild relatives of crop plants. With reference to wheat breeding it has been suggested by MacFadden and Sears (1947) that the transfer of desirable genes should be effected by the use of entire genomes by using suitable induced amphidiploids rather than by direct hybridization; (2) use of allopolyploidy in breed ing is the production of entirely new plants. The evolution of the *Triticales* (Muntzing 1943) is an unique example. This method is likely to be more useful in cases where exacting standards of quality are not requred as for example forage crops and animal feed. Various amphidiploids in the genus *Bromus* (Stebbins, 1949), amphidiploid apomicts in *Poa* (Clausen, Keck and Hiesey 1945) and Agropyron-Triticum allopolyploids are some of the useful achievements. It should be pointed out however that induced polyploidy cannot replace traditional breeding methods. These polyploids have to be considered as newly acquired breeding materials which the breeder has to study and utilise in incorporating useful genes in the cultivated plants.

Hybridization

It is well known that in Nature, hybridization has taken place between freely inter-crossing and over-lapping species. During the historical past, one of the agencies in promoting species hybridization was human interference. This as Huxley (1942) mentions, may be direct, as when new species are introduced or when they are accidently transported to new areas, or indirect, as when species meet owing to changes in ecological conditions caused by man's interference. Quite a considerable amount of hybridization has also figured in the evolution of modern varieties under cultivation. There is, no doubt, a greater variation is created by hybridization. In Nature

this variation is subjected to a natural selection, but it cannot always be assumed that they are the best from the point of view of utility for human needs. A striking example of Nature's production by hybridization is that of north Indian sugarcanes (Parthasarathy, 1946). By adopting similar methods later without the knowledge of the origin of North Indian sugarcanes i.e., by the introduction of *Sachharum spontaneum* in the improvement of Noble sugarcanes, varieties much superior to the north Indian canes have been produced by Barber and Venkatraman and most of the commercial varieties under cultivation are result of selection by the breeders. In cereals and other crops cultivated for grain, the introduction of useful genes from related species is not so simple as in sugarcane. However, with the knowledge of modern techniques as back crossing and induction of polyploidy by colchicine and embryo culture, etc., it has been possible to transfer genes from related wild species to the cultivated ones. It has been possible to bring in genes from populations which had been separated for a long time geographically. In the evolution of modern wheats some of our improved wheats have the ancestry of foreign wheats and *vice versa*.

By far the spectacular and most useful results which have been obtained by hybridization is the exploitation of hybrid vigour or heterosis in maize. According to Dobzhansky (1948) heterosis is caused by the specific interaction of gene complexes which have emerged in the process of evolution under natural selection. The hybrid maize is a creation on a large scale, a kind of adaptive polymorphism in which certain genotypes are preserved not for their intrinsic worth but because they combine effectively with other genotypes similarly preserved to give a high degree of heterozygosity in the population (Mangelsdorf, 1951).

By the cultivation of hybrid maize in U.S.A., it has been stated on rough estimate that an increase of 924,210,000 bushels of corn was obtained in 1946. In 1949, Seventy seven percent of the corn acreage in U,S.A. was planted with hybrid seed. The agricultural benefits conferred upon U.S.A. by the hybrid corn can be estimated according to Muller at a billion dollars per year. He however states that the whole cost of war time atomic energy would have been paid from this source alone!! These are facts which serve as a source of justifiable pride to geneticists. The case of hybrid corn is an eminent illustration as to how painstaking experimentation and brilliant speculation can complement each other.

Although not equalling the hybrid corn in vastness and magnitude, considerable advance has been made in other crops to effect improvement based on genetical principles. Mention may be made in this connection on the progress of evolution of high yielding wheat varieties resistant to rust and rice varieties resistant to blast. It has to be mentioned, however, that in the evolution of such varieties especially where one or two important agronomic characters have to be introduced in the existing commercial varieties, the technique of back-crossing has to be used more extensively than hitherto for achieving useful results.

Selection

It is now increasingly being felt that selection of pure lines and growing them as improved varieties may perhaps not be the correct method in view of

their narrow range of adaptability and this perhaps has led to the breeding of innumerable strains in any particular crop as in rice for the various climatic and agro-ecological regions. The study of natural populations as well as of cultivated varieties has led Hutchinson and Ghose (1937) to state, "even the inadequate description of selective forces which is all that is now possible is sufficient to show that their nature is such as to prevent the evolution of a single universal type." From the analysis of cotton crop of Central India, Hutchinson and Ghose (1937) had come to certain important conclusions regarding the composition of natural populations. The effect of selection in such populations is not to favour one particular type to the exclusion of the others and the fittest population is always a mixture of different types. In the changed conditions of environments in any particular tract no particular genotype can be the fittest and the balance is evidently kept up by a combination of different genotypes. In this connection mention may be made of the interesting experiments of Sukatschew (1928) on pure lines of dandelions. He found that altering of density of the total number of plants per plot might completely alter both the survival of seedlings and the fertility of the survivors so that the pure line whch is in force in one set of conditions would oust the rest if conditions were changed. Harlan and Martini (1938) conducted experiments with a mixture of 11 types of barley in 10 different localities over a period of four to twelve years and found that different types dominated in the different places as a result of natural selection and the proportion of different strains varied in different places. These results introduce a new problem in the breeding of better varieties for cultivation. Generally the selections are made in natural crop populations for particular morphological characters and these are later tried for their yields for three or four years and then the best performer is generally distributed as a strain. Really speaking these cannot be considered as pure lines and so perhaps this method leaves a certain amount of variability in these varieties. Selection for yield in such 'strains' have to a certain extent resulted in the production of strains with higher yield. Such secondary selections, as they are called, have been made in cotton and in rice. When it is remembered that characters which control yield are polygenic, it is likely that genetic variability in these characters is not fully exploited by the breeding technique usually followed as mentioned above. However, it has to be stressed that selection for genetic purity reduces variability and makes the variety less adaptable to changing conditions of environments which are beyond human control. To a certain extent we have to consider the natural selective forces in operation and as it has been established that nature does not favour one particular genotype, it is better not to be very rigid in making selections.

Plant Breeding

In reality plant breeding is a development of evolutionary studies. It is in fact a practical experimentation of studying the evolutionary process. A newly evolved variety by breeding is the result of man's interference by conscious selection in a variable population present in Nature or created artificially by hybridization. This method of crop improvement is perhaps the only one "which makes no payment on the purse or the skill or the intelligence or on anything more than obedience of the cultivator. It is therefore the only one which requires no change in the general system of land management. The method is plant breeding"

Since 1900, after the re-discovery of Mendel's Laws a lot of plant breeding work has been done in India and a number of improved varieties

have been evolved. The benefits of growing such improved varieties are now well understood and the need for better varieties are therefore always on the increase. All the world over, the development of knowledge in genetics is being applied to practical plant breeding and Vavilov rightly elevates plant breeding to the rank of separate discipline of biological science: "Because of the extent of practical knowledge of the subject increasing from year to year and the exclusively practical value of it in pedigree animal and plant production, breeding has, of necessity, become a special department of knowledge. So vast is the scope of classified knowledge which constitutes the study of plant and animal breeding that it has to be treated separately as a special branch of science".

In the present day there is no lack of initial materials for advances in plant breeding. A co-operative effort has been initiated by the FAO in the preparation of the world catalogue of genetic stocks in different crops like wheat, rice, forage plants, etc., and it is to the advantage of the breeder to get the initial material by mutual exchange and perpetuate the materials. An example of further advancement in such co-operation is the recent FAO project of International Rice Hybridization Scheme now in progress at Cuttack. The hybridization between the *japonica* races and several regional varieties obtained from the different *indica* growing countries of South East Asia is being effected and the hybrid seeds are being sent to the different regions for selection in the respective regions. The main object is to introduce the qualities of responsiveness to high levels of cultivation by manuring etc., as well as to introduce in varieties important agronomic characters as disease resistance, non-lodging straw, etc. I am sure international co-operation especially in the interchange of genetic stocks and new material, will enhance the progress of breeding in the different countries and will result in productive varieties. In this connection it may not be out of place to mention that advanced countries like the U.S.A. Russia and Australia have well organised Plant Introduction Bureau. The establishment of a similar Bureau of Plant Introduction in India is long over due. This matter has been brought up to the notice of the authorities concerned often and for want of adequate finances, the establishment of the Bureau is being postponed. Especially in view of increasing international cooperation in respect of interchange of plant materials, the advantage of establishing a Bureau especially for a country of the size needs no emphasis. The full assessment and utility of the various genetic stocks in the different regions of India will be facilitated by the fuctioning of such a Bureau.

Conclusion

A plea for fundamental research in genetics in India

In spite of the rapid advances in genetics, the principles of which are directly applicable to the improvement of crop plants as well as in animal husbandry and even though the importance of the study of genetics has gained recognition in various countries, it is really regrettable to note that so far no serious endeavours have been made in the Universities in India for giving the subject the importance it deserves. As early as 1929 Mrs Gabrielle Howard in her address in the Section of Agriculture of the Indian Science Congress has not only stressed on the teaching of genetics in the Universities but has also expressed that this subject should be given the importance of separate section in the Indian Science Congress. The follow-

ing words of her address still hold good though nearly 22 years have elapsed since then. "Up to the present, India has taken little or no part in the investigations on which modern theories of heredity are founded and possesses no Institution where such fundamental work can be carried out. The time has come when this *lacuna* should be filled. In the improvement of plants India stands second to none. There is no country in which greater economic results in plant-breeding have been obtained nor which is better equipped with experimental stations for such investigations. The success of this part of the subject has, however, obscured the fact that little or none of the fundamental work on the theory of heredity has been carried out in India. No university has as yet a chair or even a readership in Genetics. For the theoretical conceptions underlying the practical aspects of the subject we have to depend on the work of Europe and America. As the years pass, it will be increasingly difficult to maintain the economic work at its present level unless it is stabilised by a school of pure research in the country itself. Such fundamental research cannot be carried out by the Agricultural Departments or in any Institute devoted to economic aims. The investigator in pure genetics must be untrammelled by the necessity of producing economic results and must not be limited to working only with cultivated plants." The suggestion that genetics should form an important subject in the university teaching has been reiterated by Dr. Burns and Dr. Pal elsewhere. The Indian Agricultural Research Institute is perhaps the only Institute which is offering post-graduate teaching and research in genetics and plant breeding. Here the subject of genetical research is restricted to some of the crop plants and most of the students who take to post-graduate training do not ordinarily have sufficient knowledge of the fundamentals of genetics and after the post-graduate course they are mostly engaged in plant breed institutions where there are no equipment or the necessary incentives for genetical research, because the objective is mainly for economic ends.

I do not think we should in any way blame the universities because the conditions are such that it may not be possible for the universities to take up this subject without the proper facilities of land, equipment and qualified teachers. These are perhaps the practical difficulties which the universities have to face with, in establishing a chair in genetics.

The Agricultural Depatments of the various States have established a number of experimental research stations for the improvement of crops and most of these experimental stations are devoted to the breeding of better plants. It would therefore be a useful thing to utilise these experimental stations for providing facilities for fundamental research in genetics. In this connection Vavilov's remarks are appropriate:

"We are interested in the study of underlying principles of all aspects of general genetics: the problems of the gene, the theory of mutation, the theory of hybridization, and the problems of genetics. We are persuaded that more thorough research will afford fresh stimulus to breeding. *On the strength of this conviction, laboratories for the study of genetics are being established at our breeding stations.* At the same time general genetics will itself derive a strong stimulus from the practical work of breeding". To make a begining I would suggest that such of those plant breeding stations now functioning in the country and which have facilities for genetical work should be given the necessary grants to provide a unit for the study of fundamental genetics because of the facilities available and these stations should be recognised by the universities or affiliated to the universities as centres of post-graduate research in genetics. If this is done, I am sure that rapid progress would

be made in the development of this subject in India. It is gratifying to note that the National Institute of Sciences in India has recognised the importance of this study of fundamental genetics and that they are planning to advance funds for such of those research stations and universities as have the facilities to establish units for such research. In this connection it should be stressed that in the beginning we should not be worried over duplication of research and I am sure of rapid advances in genetics and its application to agriculture if we have sufficient number of research stations and universities taking up this research.

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40th INDIAN SCIENCE CONGRESS, LUCKNOW, 1953

SECTION OF PHYSIOLOGY

PRESIDENT—DR. N. D. KEHAR, M.Sc., Sc.D.,

Presidential Address

THE PROBLEM OF ANIMAL NUTRITION AND ITS BEARING ON HUMAN WELFARE

"*One can turn the cow into a giver of plenty instead of being the giver of scanty which owing to criminal negligence she has become to-day*".

Mahatma Gandhi.

I am deeply conscious of the honour you have conferred upon me by electing me to preside over the deliberations of the Section of Physiology of the Indian Science Congress Association. It is a matter of supreme gratification for a research worker when his humble efforts in the cause of scientific progress are appreciated by his colleagues and coworkers. This is perhaps the first time that a worker from the field of animal husbandry engaged on comparative physiology has been made the President of this Section. May I take it to be a sign that Animal Husbandry in general and Animal Nutrition in particular is given the recognition that it deserved long ago.

It must be conceded that next to air and water food is the chief item for the preservation of life in both man and animal. The primitive man lived a strong and healthy life with a variety of nature's bounties at his disposal. Likewise, Abraham did not worry about a balanced ration for his stock, as pasture grass from fertile soils provided all that was needed for maintaining normal health and milk production. But according to the basic principle enunciated by Malthus (1780), "there is no bound to the prolific nature in plants and animals but what is made by their crowding and interfering with each others means of subsistence". Thus, in the course of centuries, the human and animal population increased so much that the current production from the land fell short of the requirement. Anthropologists believe that preliterate and medieval populations were kept roughly constant by natural factors, like, famines, epidemics and wars. But now with the rapid advances in the control of epidemics, the establishment of U.N.O. to settle conflicts of diverse nature by aibitration and the increase in life expectancy from 30 in 15th century to 70 years (in U.S.A.), the food available per person has continued to decline. The world population increased nearly three-fold during the past 200 years, from 875 to 2400 million and is increasing at the rate of 26 million or 1.2 per cent per year.

The current increase in world population i.e. 1.2% is not very different to that in India . In U.S.A., prior to 1900 A.D. the annual increase was about 3%, which is higher than in any Asiatic country. Due to increased

demand for food, most of the world's accessible arable land is being cultivated for food production by modern methods. The present productive ceilings can be raised but subject to the "law of diminishing increments". Europe was in the same cramped position in the 15th century as India is now. But the discovery of America by Columbus—a territory six times larger than Europe— along with the newly colonised areas like New Zealand, Australia and South Africa gave them the much needed area for expansion. Inspite of all this John Boyd Orr, the first Secretary General of F.A.O. remarked that two-thirds of the world's people were, even before the war., undernourished all the time. Norris E. Dodd, Director General, F. A. O. has furthdr pointed out that, "the marginal millions do not get enough to eat, which means a race with death".

In India, which is chronically a food deficit country, where four-fifths of the cultivable land is still to depend upon uncertain rainfall and where the productive capacity of the land is at a static stage and is adversely affected frequently either by servere droughts or heavy floods, the problem of adequate supply of food has always been the cause of deep concern. This was further complicated by the stoppage of food imports from Burma and Indo China during the last global war. A further reduction in food supply was sustained by the partition of the country in 1947, whereby the granary of the country went to Pakistan. These deep dents in the food supply sector attracted the attention of both the Central and the State Governments and immediate steps were taken to make up the deficit by more intensive internal production. A Grow More Food Campaign was started by principally bringing more land under cultivation. But contrary to expectations the increase in food production could not keep pace with the increase in population. The acute shortages of food existing even now have brought out the question that perhaps all is not well with our present production method. A number of point viz. the depleted condition of soil, use of inferior quality of seed, the vagaries of weather and difficulties in procurement have been cited from time to time as the causes leading to the shortage of food.

Vital role of livestock in agricultural operations—Efficiency of animal determines food production

In this address I shall like to focus attention on another important aspect which is often lost sight of, and which, to my mind, seems to play a vital role in the augmentation of food supply in the country. I am referring here to the degenerated condition of our livestock specially the cattle and to stress that mal-nutrition is the greatest single factor in bringing about this degeneracy.

From time immemorial, cattle and human beings have played an integrated part in the production of food. Cattle is not only used in this country for ploughing the land but also in other agricultural operations, like, thrashing the corn, irrigating the field and also in carrying the agricultural products from the village to the market. The cows supply us with the natural best food i.e. milk. In addition, cattle supply both dung and urine which, if propry composted and returned to the field, can bring new life to the soil. The annual returns from animal labour and animal roducts, according to Datta[2], come to about Rs. 3000 crores. In spite of this vast contribution, it may be stressed that these returns could have been much more, had the animals been well looked after so that the best in them could

have been brought out. Unfortunately, however, as will be detailed later, our livestock exist on retions bordering on starvation. This chronic malnutrtion has not only been responsible for the puny size and unthrifty and unproductive nature of our catte but has also made them easy prey to a number of diseases. A pair of Indian cattle can plough on an avrage only 10 acres of land while the Egyptian bullocks are able to produce 7 times more work[3]. An average Indian cow produces only 413 lbs. of milk per lactation[4], whereas, corresponding figures for Switzerland, Holland, Denmark, United Kingdom and United States of America are 6498, 7559, 7005, 5576 and 4126 pounds respectively.

Besides cattle, other livestock like goat, sheep and poultry also produce milk, meat and eggs—valuable quality foods, which go to enrich the human diet. Due to lack of proper feeding these animals are also poor producers of their kind.

Food requirements of human beings—the target—the shortages

The effect of this degeneracy of our livestock on human food supply may now be discussed. The population in India is increasing at the rate of 1.2% per year. Based on the present number of 366 millions heads, we will have about 300 million adult units to be fed by 1958 during which the Five Year Plan is to operate An Expert Committee consisting of nutrition workers in India has recently calculated the requirements per head per day as given in Table 1.

Table I

Showing the daily requirement per adult unit of different categories of food stuff

Cereals	14 ozs.
Pulses	3 ozs.
Vegetables	10 ozs.
Fruits	3 ozs.
Milk	10 ozs.
Milk	10 ozs.
Sugar or gur	3 ozs.
Fats	2 ozs.
Fish or meat	3 ozs.
Egg	one a day

The annual requirement in tons of cereals works out to be 43 million; pulses, 9 million; vegetables, 30 million; fruits, 9 million; milk, 30 milllion; sugar or gur, 9 million; fat, 6 million; fish or meat, 9 million; besides 110 thousand million eggs.

The current production is low in all the catagories mentioned above. But it will be found that the availability of animal products falls far short of the requirements. Thus, whereas cereal production amounts to 41 million tons that of milk is only 18 million tons and meat 0.8 million tons and of eggs only 2790 million. Out of the total milk produced, about 11 million tons are utilized in the manufacure of milk products like ghee, dahi and khoa etc. In other words, the consumption per adult unit per day of fluid milk is about 2 ozs., of meat $\frac{1}{4}$ oz. and of eggs about 9 per year.

It is well recognised that a liberal supply of animal products for human consumption is of special importance for the maintenance and improvement of health both because of their nutritive values and also because of their degree of acceptability in the diets of most peoples. Wills[5] pointed out that a lack of animal protein is considered responsible for the occurrence of the syndrome variously referred to in Africa as "Kwashiorkor". Such cases of malignant malnutrition are more common in peoples of the world who consume diets primarily of plant origin. Morrison[6] stated that the protein of the cereal grains is of rather poor quality. Maize is low in the two essential amino acids, namely, lysine and tryptophane. To a somewhat lesser degree, this is also true of oats. Wheat and barley are deficient in lysine.

We know that, in general, mixtures of proteins of animal and plant sources provide a more efficient amino acid mixture than the latter alone. Consumption of animal protein[7] has often been regarded as an excellent index

FIG.1. SHOWING CONSUMPTION OF ANIMAL PROTEIN PER HEAD PER DAY. (gms)

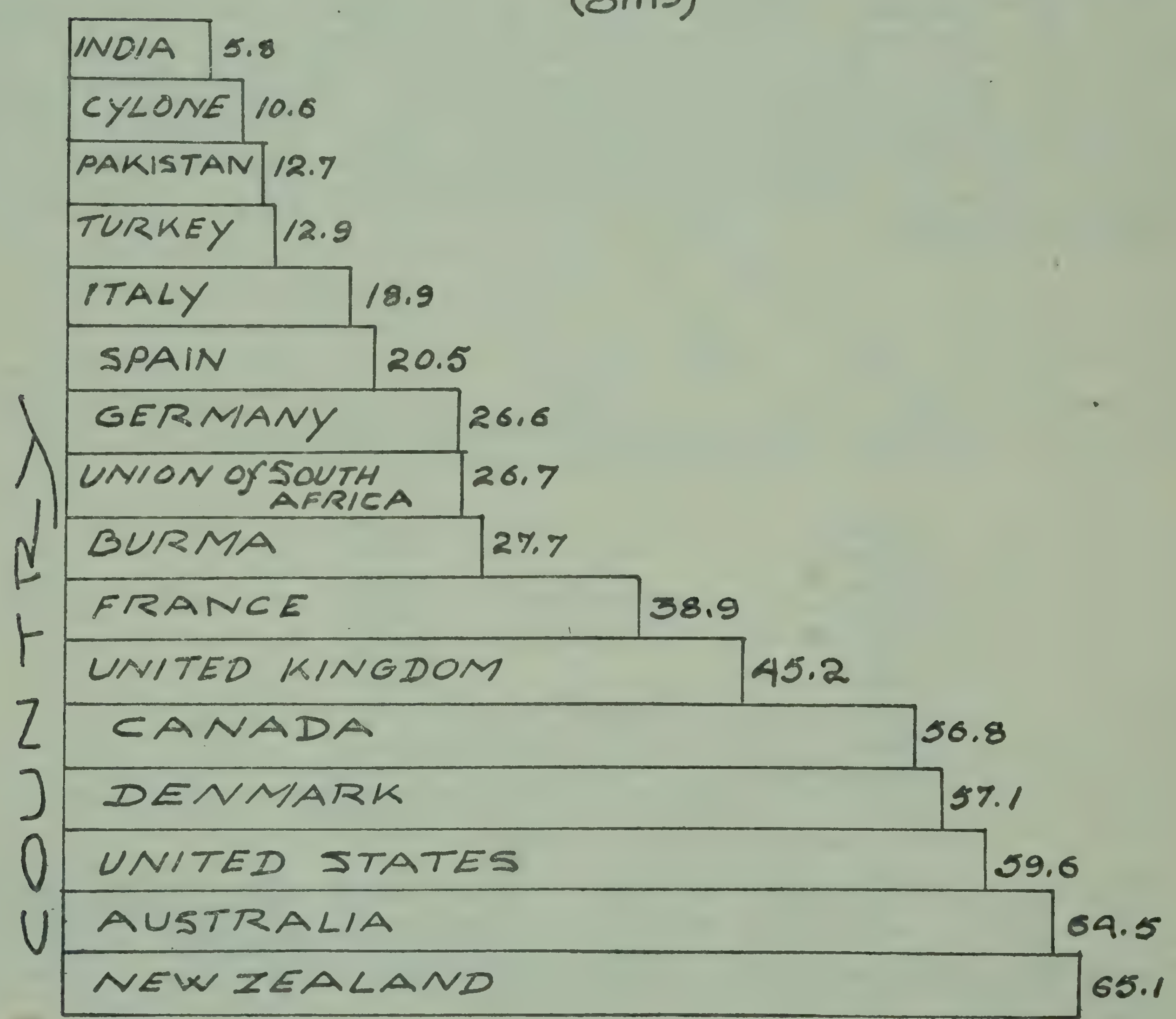

FIG. 1

of the state of nutrition, not only, because they contribute to the diet, amino acids most likely to be lacking in vegetable protein, i.e. lysine, methionine, threonine and tryptophane but also because consumption of animal protein generally varies in the same direction as the consumption of B-vitamins and most of the minerals. Milk seems to be the most economical supplement to food of plant origin because it contains the limiting amino

acids and B viamins, including B_{12}. Its slightly soluble carbohydrate, lactose, passes into the intestine providing a favourable medium for vitamin B synthesis and promotes assimilation of calcium and phosphorus. Further milk is of special importance in the nutrition of infants, children and pregnant and nursing women, Yet milk is one of the very commodities being available to the extent of only about 2 to 3 oz. per head per day Datar Singh[8] remarked that milk is more expensive in India than anywhere else in the world. Ghee (clarified melted butter) has been considered as a superior fat to crude, refined or hydrogenated vegetable oils or lard.[9,10,11,12].

In regard to the minimum and optimum allowance of animal protein per person per day for maintaining normal health there is no general agreement among nutrition experts. An indication of the extent to which diets are deficient may be gained by using a comparison suggested by Morris[13]. He used 70 gms. total protein and 33 gm. animal protein as optimum levels of intake. These levels have also been recommended by the United States National Research Council. According to this standard the availability of animal protein in India per person per day falls far below the requirement, being only 5.8 gm[14]. (Fig. 1)

According to the data collected by the F.A.O,.. it has been estimated that except Indonesia and China the animal protein available in India per head per day is least when compared with 58 other countries of the world from where statistical information is available.

Further, the valuable data collected by the F.A.O. shows how consumption of food of animal origin declines rapidly with decline in the fertility of land and per capita income of a country. For instance 25% of the dietary calories are obtained from food of animal origin in prosperous U.S.A., Australia and New Zealand; 15% in less prosperous Europe and in most of South America; and only 2·7 % in economically poor Asia. Table II shows available protein (total and of animal origin) in relation to calories in several different countries.

TABLE II

SHOWING AVAILABLE PROTEIN (total and of animal origin) IN TELATION TO CALORIES

Country	Available food supplies per person per day		
	Calories	Total protein gm.	Animal protein gm.
New Zealand	3249	96.3	65.1
Australia	3165	95.1	64.5
United States	3128	90.2	59.6
Canada	3062	92.3	56.8
Switzerland	3096	93.7	49.5
United Kingdom	3030	90.5	45.2
France	2740	98.9	38.9
Burma	1937	66.5	27.7
Pakistan	2028	53.9	12.7
Ceylon	1918	43.2	10.6
Japan	1834	49.6	7.8
India	1621	42.5	5.8

There is ample evidence to show that unless properly balanced diet is available, normal levels of growth cannot be attained. McCay et al [15,16] found that there is a direct relation between growth rate and life span and that on a diet deficient in one or more nutrients the animals show a retarded growth and may die prematurely. When the growth rate and life span of mice kept under uniform conditions of diet was compared, it was found[17] that animals having a rapid growth lived on an average longer than those which grew more slowly. These observations indicate that a high quality diet adequate in all essential nutrients, exercises an important influence on life span. Such observations show the influence of the dietary regimen in early life upon the subsequent evelopment of disease and hence upon the life span. Tannenhaum[18] has remarked that if observations on rats can, to any extent, be applied to man, a high quality diet, adequate in all essential nutrients, with moderate restrictions of calorie intake tends to extend life span.

Inspite of the above knowledge being available about the indispensability of animal products for human welfare it is noticed that while most of the efforts of the Grow More Food Campaign have been directed towards meeting the 5 to 10% deficit in cereal grains, not much attention is being given to improve the supplies of "quality foods" viz. those of animal origin.

Indian cattle possess high production potentiality

It has been found by repeated experiments that when proper attention is given to supply the balanced ration to animals in India, their productivity is increased immediately. Thus the milk yield may be augmented by 50 to 90 per cent[19,20] and egg yield by 100 per cent[21] through proper feeding alone. Not much work has yet been carried out in India on the improvement of meat production through proper feeding. The Izatnagar findings, however, show that by incorporating adequate quantities of vitamin A in the diet of sheep the weight of the animal is 22 increased by 50 to 70 per cent.

It is true that scientific feedings alone will not meet the total shortages in the supply of animal products. If, however, the productive capacity of the Indian livestock is to be increased the first essential course should be their proper rehabilitation through feeding and management. When that has been achieved, the stock can then be progressibely improved upon by sound breeding policy. If, however, breeding work is taken at first as was envisaged in some of the projects we may be placed in a position where improved progenies may deteriorate rapidly through want of adequate feeding.

Scarcity of draught animals

So long we have been discussing the direct contribution of livestock in supplying human foods, the indirect contribution is of similar and even greater importance. The net area cultivated in India has been raised from 228 million acres in 1946-47 to 251 million acres in 1950-51; yet the total food grains including pulses produced has remained more or less stationary at about 46 million tons. Unfavourable weather conditions, lack of rain in some places and floods at others have been given as causes for this lack in increase. But to my mind a major factor appears to be the shortage of working bullocks. India possesses about 60 million bullocks of over 3 years age. Buffalo bulls have been left out as they have much lower efficiency for doing outdoor work.[23] Out of this number 54 million are found in the rural areas.

Leaving aside 1 million breeding bulls, the number which can be utilised for working purposes is 53 million. It has been estimated that 10 per cent of these are unfit for work due to old age or diseased conditions. The net number of working bullocks comes out to about 48 million. Since a pair of Indian bullocks can plough only 10 acreas of land, the number of working bullocks, if totally employed, can cultivate only 240 million acres. It will, therefore, be seen that though the available number of working bullocks was just sufficient in 1946-47, this number has been totally insufficient for ploughing the 251 million acres in 1950-51. It will therefore be a moot question whether it is possible to increase the acreage under our present condition of animal husbandry.

By supplying proper food it is possible to increase the efficiency of our existing stock of working bullocks by at least 20 per cent. Under such conditions the present number of bullocks, without undergoing any long term genetical improvement, can easily plough over 275 million acres. This scarcity in working bulls, which form the backbone of Indian agriculture, is reflected in the soaring prices of such category of animals. In Delhi a a pair plough bullocks, which used to cost Rs. 101 in 1939 were being sold at Rs. 1231 in 1947. In Madras corresponding prices were Rs. 175 and Rs. 1300 respectively. On account of this scarcity and high prices of plough bullocks it is being advocated that cows specially dry cows may be used for this purpose.

Limitations of tractors for agricultural operations

From other quarters, an intensive use of tractors for tilling the land is being urged. There is no doubt that for large scale deforestation and rehabilitation, tractors can do enormous srvices. After examining the limitations in the use of tractors Acock[24] found that even though there has been a rapid increase in the number of tractors since the early part of this century, over 85 % of the draught power used in farming operations in the whole world is still provided by animals. Under the Indian system of agriculture with its complicated land tenancy structure, fragmentation of the cultivable area, difficulty in the availability of spare parts, it is doubtful how far the routine use of tractors, even if they can be used, will be economical. Moreover when the tractors are used it is necessary to add artificial manure in order to maintain the productivity of the soil. In the catte, however, we have nature's own manure factory. A cow weighing 800 lbs. excretes about 6000 lbs. of urine and 16000 lbs of dung annually. By making use of the coarse roughages cattle give out in their excreta, large quantities of nitrogen, potassium and humus which go to enrich the soil.

Cattle and human beings—relation of interdependence not of competition

The intimate relation which exists between man, soil and animal was recognised long ago by the ancient cultivators and it is for this reason that cow had been held in great reference in India from time immemorial. This integrated relation between cattle and man is also reflected in another way. It has often puzzled some economists as to why there is always a bigger concentration of cattle in areas of India where the human population is also dense. If cattle and men were competing for the available land, the pressure of human population would have thinned out the cattle population.

Contrary to the belief that the livestock compete with men for the available food, the ruminants harvest the vegetation on marginal land not suitable for cultivation, and consume high cellulose feeds like hay, straw, bran and husks which are not suitable as food for man. Pigs and poultry utilise kitchen and farm wastes that have nutritional value and yet not edible by man, and convert it into highly prized human foods. These animals, therefore, are not only useful as scavengers but also as converters and refiners of inedible foods into products of high nutritional value. Moreover as Phillips[14] has stated that farm animals serve as "shock absorbers" consuming surplus grass and grain in periods of abundance and provide food for man in lean years. This interdependence of one species on the other can, thus easily explain the paradox of co-existence and it folows as a carrollary that improvement in the status of one species will be reflected in the other.

During the last few decades, however, the blind urge to produce some bulky food to appease the hunger of the growing population had led to the encroachment of grazing fields and to felling of trees on a large scale to provide for growing cereal grains. The by-products of such crops have very little feeding value and the loss of grasslands has led to the deterioration of feeding standards of the cattle, resulting in a decline of their productivity. The scarcity of fuel wood has led to the use of cattle dung as fuel, thereby depriving the soil of useful manure. This vicious circle has thus been created giving the present picture of depleted land, weak cattle and semi starved human beings.

Magnitude of livestock and poultry population and availability of feeds

Sufficient arguments have been adduced and data marshalled to point out the fact that improvement in human food production is dependent to a great extent on the improvement of the feeding standard of our animals, particularly cattle. A few more facts about our animal population and their feed requirement are being given now to show the huge disparity between the availability and the target for minimum requirement.

According to the 1951 Livestock and Poultry census India possesses 60 million bulls, 48.5 million cows and 41 million young stock. Moreover, there are 6.8 million buffalo bulls, 21 million female buffaloes and 14.5 millon young stock under three years of age. In addition, there are 40 million sheep, 47 million goats, 1.5 million horses and mules, one million donkeys, 4 million pigs, 70 million poultry and half a million camels. The magnitude of the livestock population can be judged when it is stated that the bovine population is almost equal to that in the whole of Australia, Newzealand, North America and Europe (excluding Russia) put together.

In attempting to assess the availability of animal feeds in this country, it becomes clear that in the absence of basic data, which is wanting at present it is not possible to arrive at an accurate estimate of supplies. All that is possible is an approximation.

Out of the 251 million net acres sown, only about 2 million acres are kept apart for growing fodder crops. Besides this, it is assumed that for grazing on grasses grown during the monsoon on the road side, canal banks and current fallows livestock received their full maintenance for three months in the year and half the maintenance ration for another three months. In addition, it is the practice to allow the young calves to suckle one teat of

its dam for 2-3 months. The milk which is allowed for calf feeding may, therefore, be assumed to be one fourth of the production for 3 months that is about one million tons. The rest of the food available is obtained from the byproducts of the crop processings, such as straw, oil cake, bran, pulse husk and cottonseed etc. The feeds available from various organized sources in million tons are shown in Table III.

TABLE III

	Available feeds on dry matter basis	Digestible protein	Starch equivalent
	in million tons		
Fodder crop	36.1	1.8	18.0
Grasses	—	3.4	33.0
Straw	93.0	0.5	23.3
Oilcakes	3.2	0.9	2.1
Bran	1.5	0.1	0.8
Pulse (husk and chuni)	1.5	0.1	0.7
Cotton seed	1.4	0.2	1.0
Milk (consumed by calves) as fluid	1.0	—	0.6
Total		7.0	79.5

In calculating the requirement of cattle it may be assumed that 40 per cent of cows are in milk and are producing, on an average, 5lbs. milk per cow and 10 lbs. of milk per buffalo cow per day, the calves are gaining at the rate of 1lb. a day and the bullocks work at the rate of 4 hours a day. According to these assumptions, the total annual requirement for our bovine stock would be 26 million tons of digestible crude protein and 206 million tons of starch equivalent. It may be mentioned here that these figures are based on calculations according to the Western data. Work carried out at Izatnagar by Kehar and Mukherjee[25] has shown that the maintenance requirement of Indian catte is 25 per cent less than that advocated by Morrison. Against this fact, it may, however, be pointed out that in the above calculations, the requirements of other type of livestock like sheep and goat, horses, poultry, pigs etc. have not been taken into consideration. It is true that under our present system, sheep, goat, poultry and pigs maintain themselves solely on what they can get from from grazing and foraging, but if we are to utilize these animals and brids to the maximum extent they also must be fed properly. Taking all the facts into consideration, the target requirements for livestock may be kept at 30 million tons of the digestible crude protein and 210 million tons of starch equivalent. This means that the available supply of digestible crude protein and starch equivalent from our organised sources is 23 per cent and 38 per cent of the required amount. No wonder that our cattle are stunted and low producers.

WAYS AND MEANS TO FILL UP THE GAP

At first sight it may appear that it is impossible to gain self-sufficiency in animal feeds. In fact some economists have advocated that cattle may be slaughtered wholesale and the very best amongst them maintained so that the available feed supply may suffice for them. This point of view is based

on the theory that cattle and human beings are in competition for the available land. It has however, already been pointed out that an integrated relation exists between man and cattle in India and that the existing number of cattle except the non-producing and decrepit cannot be reduced without effecting human food production. On the other hand, it is not possible to maintain livestock on human food by-products alone. Some land will have to be diverted for growing cattle fodder. The question is, whether, that is at all possible in India. In the following paragraphs I will attempt to show that with an intensive effort and well-coordinated policy, India can have sufficient food for both human beings and livestock.

(a) *Optimum use of available cultivable land*

The net area in India under principal food grains is, at present, about 178 million acres. By reclaiming about 22 million acres of cultivable waste land, the total area can be incresed to 200 million acres. Further, most of the land is cultivated only once in the year. But by suitable irrigation measures in which the multi-purpose big dam constructions are sure to play a prominent role, half of this area can be brought under plough more than once. The total area available will then be 300 acres. Besides these, there are about 50 million acres devoted to cash crops like cotton, jute, tea, tobacco etc. and another 50 million acres are kept apart as current fallows. Out of this net total of 400 million acres, 200 million acres can be allotted for growing cereals and pulses. According to Nair[26] an acre of land which used to produce 6 to 10 mds. of wheat and about 200 maunds of potatoes now produces under the Etawah multi-purpose community project 30-35 mds. of wheat and 600 to 700 mds. of potatoes. With the initiation of 52 community projects and 20 development blocks spread over the length and breadth of the country and with improved seed and water and manure supply, this area will be sufficient to provide human food grains even after keeping apart some for seed purposes. If 70 million acres more are intensively cultivated they will provide sufficient oil seeds to supply the human requirement of fat and will also help in a larger way to meet shortage of cocentrates for animals. For the remaining cash crops a total area of 30 million acres may be sufficient. Keeping apart 15 million acres for vegetables and fruits we are left with 85 million acres (out of which 50 million acres are current fallows) which should be kept for growing fodder crops.

(b) *Fodder crop-grain rotation increases yield.*

The utilization of current fallows for growig fodder crops especially legumes is a sound policy as this not only supplies the urgently needed animal feeds but it has been repeatedly shown that a grass-grain rotation increases the yield of grain considerably. The following illustration may serve to bring out this point more clearly . The present average yield of wheat per acre in India is 600 lbs. A cultivator possessing 3 acres of land will, therefore, be growing 1800 lbs of wheat and 3600 lbs. of wheat bhoosa. Leaving aside 180 lbs. of grains for seed purposes, the rest will be sufficient for a family consisting of 4 adult units on the basis of 1 lb. per head per day and will leave a surplus of 180 lbs. which when sold will bring very little cash for purchasing the other necessities of life The wheat bhoosa produced will provide sufficient maintenance roughage only for 7½ months for one bull and the wheat bran obtained will provide necessary proteins for 20 days only Assuming that the animal was getting 4½ months maintenance ration from grazing, it follows that from the by-products from 3 acres of land it will

be possible to provide the roughage requirement for one year and protein requirement for 5 months in the year only for one bullock. It may be noticed that no provision for work production can be made out of the available feeds.

On the other hand, it has been shown at the Indian Agricultural Research Institute, New-Delhi, that wheat grown after berseem gives an yield of 1200 ℔s. of grain and 2400 ℔s. of straw per acre in a three year rotation process. Therefore, 2 acres of wheat will give 2400 ℔s. of grain and 4800 of straw while the remaining acre will give over 40,000 ℔s. of green berseem. Thus, not only, there will be more grain grown on less land allowing the cultivator to sell more wheat, but the berseem and by-products of wheat plus only a small quantity of concentrate will be able to maintain not only two bullocks for medium work but also a cow giving 5 ℔s. of milk daily. The efficiency and economical side of mixed farming thus becomes apparent.

Time—an important factor. The evolution of a mixed agricultural policy is, however, likely to take sometime to develop. Questions of legislation, consolidation of fragmented holdings, supply of irrigation water, production of improved seeds for human food and cattle fodder plants —all this comes under a long term policy. That our Government is conscious of their urgency is apparent from the multi-purpose projects which have been set afoot. But in the following paragraphs we may point out certain steps, which can be immediately taken to augment the food supply of the country and therefore mitigate, to some extent, the effect of acute shortages.

(c) *Subsidiary feeds*

The Animal Nutrition Division of Indian Veterinary Research Institute Izatnagar realized the urgency of the provision of more feeds for the livestock and since 1940 investigations have been in progress to discover new feeds for animals from, hitherto, untapped sources. A number of substances, which were going waste, have ben utilised and the following have been found useful after proper processing

(1) Wild grasses like Kans[27] (Saccharum spontaneum) and Munj[28] (Saccharum munj) have been found to form a maintenance ration by themselves when cut at the pre-flowering stage. Even at the ripe stage these grasses when mixed with molasses can be fed profitably.

(2) Mangoseed kernel[29], Jaman seed[30], Tamarind seed[31] fish meal[32] and entrails[33] from slaughter houses, cassia tora seed[34], rain tree fruit[35] can be utilized to supply valuable concentrates, which can be used to replace subsantial part of gra inmixture in a producing ration.

Besides these, sugar cane tops[36] Mahua flowers[37] bajra husk[38] and jowar husk, Kantiara[39] etc. etc. which are being wasted now, have been shown to possess substantial nutritive value. If ways and means can be found out to impress upon the cultivators about the utility of these substances as cattle feeds and the resultant profit in the form of better work and more milk production, there is not doubt that, these substances which are being wasted now can be profitably used. The extent of ocurrence of such materials can be gauged from the fact that from these sources about 11 million tons of concentrate feeds and 300 million tons of roughage providing 4.8 million tons of digestible crude protein and 26.5 million tons of starch equivalent, worth several hundred crores of rupees will become available every year.

(d) *Use of nitrogenous foods like urea and food yeast to replace concentrates.*

Modern advances in chemical and food technology can also be utilised to some extent for meeting the food shortage. It has been found out that ruminants can utilise simple nitrogenous compounds to synthesise, a part of their protein requirements, so that compounds like urea can replace a substantial proportion of costly protein food in cattle ration. The problem of utilising the molases produced in sugar factories is an urgent one. Efforts have been made to feed molasses mixed with bagassee screenings[40] and such a mixture has been found to be useful in supplying the energy needs of a working bullock[41]. A better procedure will be to utilise the molasses in the preparation of food yeast—a highly nitrogenous protein food which can be extensively used for cattle ration.

(e) *Preservation of surplus grasses as silage.*

Little interest has been shown in India in peserving surplus grass either as hay or silage. The dearth of pasture land is perhaps one of the main causes. However, during the monsoon weather there is abundance of green fodder. Hay making at this stage is well nigh impossible due to adverse weather conditions. By the time the monsoon is over, the grasses reach a late stage of maturity, when their nutritive value is very low[42]. If, however, the grass can be cut at the pre-flowering stage and ensiled, its nutritive value can be maintained and the silage can be fed during late winter and summer months when green feeds are scarce. Fodder crops like jowar can also be ensiled to provide succluent feeds during these dry periods.

The term ensilage is connected in the mind of many people with expensive concrete silo towers, efficient chaff cutters and plenty of man and machine power. It has, however, been shown[43] at the Animal Nutrition Laboratories at Izatnagar that good quality silage can also be prepared in an ordinary manner and a small size silo pit of 8′x5′x4′ dimensions can be used to ensile 100 mds. of green fodder. Such a pit can be easily dug and filled in 4-5 days by 2 men only and the silage made meets requirements of 2 bullocks for 2 months. Hence, with such two pits, the worst period of the year when succulent fodder is not available from the field can be tided over. It is considered that for ensiling jowar and other coarse fodders the use of a chaff cutter is very helpful. But the persons who do not possess such a machine, can yet make silage from other materials. It has been found out by us that shed tree leaves when mixed with berseem or lucerne[44] or other leguminous fodders and ensiled yield a product which is highly palatable and forms a maintenance ration by itself. Roughages like rice straw etc. can also be imporved by ensilage with leguminous fodders.

Silage feeding is also beneficial for preventing some deficiency diseases if properly ensiled. Green fodders preserve their carotene content to a large extent so that good quality silages are rich source of vitamin A. Avitaminosis—A in cattle is widespread in India and night-blindness has been reported from all the states of India. Blindness in calves is also quite prevalent especially in the urban areas. A good proportion of calf mortality is suspected to be due to a shortage of supply of vitamin A to the dams. The quantity and quality of milk is also seriously affected. These factors are not astonishing when it is remembered that our cattle generally receive green feed for about 3 months in the year i.e. during the monsoon months. In the rest

of the year they get straws or hays which contain little or no carotene. The silage feeding for maintaining health and efficiency is of urgent necessity. With proper demonstrations and advice it is felt that silage making both on a snall or large scale may be made popular throughout the country.

(f) *Tree leaves as fodder.*

Another important source of feeds are the tree leaves. These are generally recognised as scarcity fodders; but extensive investigations[45] carried out at the Animal Nutrition Laboratories, Izatnagar have shown that many trees supply fodder which can maintain cattle without any further or very little addition of concentrate. It has further been demonstrated that mature trees can be lopped periodically without doing much damage to the trees so that a large bulk of fodder that has not yet been taken advantage of can be made available throughout the year. There is a wide scope of extending this source of fodder supply. Waste lands, canal banks, and road sides may be planted with fodder trees. In addition to supplying fodder, the lopped off branches may be used as fuel, so that a good proportion of cow dung which is being wasted as fuel can be conserved and used as a manure. In passing, it may also be stressed that tree leaves are a good source of vitamin A supply.

(g) *Proper use of forest grass.*

The utilization of forest grasses through grazing or hay making has been attracting the attention of animal husbandry workers for a long time. There is no doubt that a large amount of grass is available in the forest areas, but most of it cannot be used at the present moment. The fringes of the forests are over-grazed. Attempts are now being made by the Forest Departments of several states to bring about improvement by rotational grazing, by limiting the number of cattle by closure during certain seasons of the year etc. It has also been advocated that such areas may be kept apart for good type of cattle and one of the future policies of the Government is to remove dry cattle to forest areas where they can be maintained at a cheap cost and to send them back to urban areas when they are in an advanced stage of pregnancy.

Preservation of forest grasses as hay has also been recommeded. I am, however, afraid that this policy will be hardly economical on account of the difficulties of cutting at the time when the nutrients are at their optimum level and also of labour and high transport charges. I may suggest that sheep and goat keeping on a commercial basis may be practised near the forest areas and tree leaves and forest grasses may be more effectively us for producing meat which can be transported to distant areas with greater ease.

(h) *Improvement of grassland to augment human and animal food.*

It is well recognised that in India there are no proper type of pastures. But if animals are to give the maximum return at the lowest cost, proper attention should be given for the development of improved grasslands however small may be their dimensions.

Grass as used in the broad sense include legumes and other herbages. The first essential in the diet of a herbivora is a food which has bulk as well as high food value. A mixed pasture provides these requitites and constitutes the best and cheapest food for maintaining livestock in normal health

and growth as also for the production of reasonable quantity of milk. In Norway 50 per cent of the feed consumed by livestock consists of pasture herbages. Likewise, in Finland 62%, in Holland 80% and in U.S.A. 51 per cent of the nutrients are derived from hay and pasture. Semple[46] points out that in North West United States cows with a resonable high level of production are maintained on good summer pastures without concentrates.

The fundamental Biblical truth that "all flesh is grass" holds good today as in the past with probably a slight addition that 'all flesh and milk is grass'.

The available pastures should be improved by utilising existing scientific information with regard to reseeding, top dressing with nutrients like phosphate, calcium or trace minerals as are deficient in particular areas, control of grazing, water conservation measures, burning hard stumps, modification of flora and control of unsuitable plant species. Such attempts may be made singly or in combination towards increasing the output of plant nutrients and hence of livestock products from a given area of land. By adopting some of these methods grass production in certain pastures increased by 50-70 per cent in Oklahama and Montana in U.S.A. and in Australia.

Sears[47] reported that in Newzealand encouragement in developing mixed pastures of grass and clover doubled the percentage of protein and increased the grass production by six times. Thus, by undertaking nationwide programme of excellent research and its application, the people of Newzealand have shown the remarkable possibility of increasing food production by improving both natural and cultivated pastures. These examples indicate the extent to which grass land may be more effectively utilised, to meet man's needs for animal products.

Besides the usefulness of grass in increasing food production, it is one of the most important factors in soil building. It has been shown that soil formed under grass is not only rich in humus and nitrogen but is protected against erosion by wind and rain.

Difficult as this task may appear, it cannot be considered unsurmountable because of the remarkable characteristic of grass and legumes to colonise the most unpromising land which are unsuitable for crops due to high alkalinity or acidity as well as lands which are too rough or stony for cultivation. Since grass grows so rapidly under a wide variety of conditions areas of land which are otherwise unproductive should be developed as grazing areas to augment food production.

Grasses have also been reported to play an important part in soil sanitation. If cereals alone are grown on a particular land repeatedly, they often become more susceptible to pathological fungi and bacteria. A proper rotation of legumes and grain provides unfavourable environment to these organism.

Experiments carried out at the Cornell Agricultural Experimental Stations have shown that the digestible nutrients cost twice as much in hay, 3 times in hay silage and six times as much in grains and commercial by products as the digestible nutrients in pasture.

Limited facilities for Animal Nutrition Research— Need for expansion

The value of research work for utilizing all the available feeds to the maximum benefit cannot be over-rated. Balanced feeding is not only essential in getting best out of the animal but also helps in preventing

unnecessarywastages. Animal nutrition research in India is of fairly recent origin and facilities for extending the scope of fundamental and applied research are extremely limited in relation to the vastness and significance of this problem.

The history of systematic research in Animal Nutrition in India dates back to the year 1921, when Dr. Warch, the Physiological Chemist initiated work on the chemical composition and nutritive value of animal feeds at the Indian Agricultural Research Institute, Pusa. In 1923, the section was transferred to Bangalore, where it formed one of the two wings of the newly organized Indian Institute of Animal Husbandry and Dairying. Besides the nutritive value of some fodders he also worked on the acid, base, nitrogen, sulphur, calcium and phosphorus balances of cattle kept on different types of feeds.

A contemporary group of workers led by Dr. Lander started work in 1923 at Lyallpur and collected a mass of information on the nutritive value of various North Indian feeds. Dr. Lander was the first person in India to stress that the nutritive value of a fodder is dependent to a great extent on the soil on which it is grown. After the retirement of Dr. Lander in 1946 the torch lit up by him has been kept alight by his talented colleague Dr. Lalchand Dharmani, first at Lalpur and then after partition at Ludhiana.

Dr. Warth retired in 1935 and the section was transferred in 1936 by the Government of India to Izatnagar to form the nucleus of the Central Animal Nutrition Institute under the administrative control of the Director I.V.R.I. Dr. K. C. Sen was appointed to hold charge of the Division and under his able management research investigations on Physiological, Biochemical and Pathological aspects of Animal Nutrition were taken on hand. After Dr. Sen's appointment as Director, Indian Dairy Research Institute, Bangalore in 1944, I took charge of the Division of Animal Nutrition. Since then besides being an All India Centre for training in Animal Physiology, its activities have been extended in several other directions.

In Addition to these centres of multi-purpose research, work on different aspects of animal nutrition, chiefly of local interest was carried on at a few places under the auspices of the I.C.A.R. which was established in 1929 as a result of the recommendations of the Royal Comission on Agriculture. In the early thirtys, work on the nutritive value of paddy straw was started in Dacca, Bengal and its poor nutritive quality was brought to light by Chatterji and Associates. Similarly, investigations on the chemical composition of indigenous fodders at Coimbatore initiated about the same time by Ramiah and Associates showed a low phosphorus content in many of these forages. Some work on the mineral content of grasses of Bihar was undertaken in Sabour, Bihar.

In 1938, invstigations on the nutritive value of lucerne and berseem and the effect of replacement of some part of the roughage by these fodders were carried out at Bharari, Jhansi, U.P. by Das Gupta and Associates. Later on work in this centre was extended to examine the comparative feeding value of several straws of some of the common pulses.

In 1943 the Agricultural Institute at Anand established an Animal Nutrition Section and work was taken up by Ray and Patel on the effect of different feeds on the quality of milk. Recently, with the financial help given by the I.C.A.R. a scheme to investigate the nutritive value of acquatic grasses was started at Gauhati.

The work completed so far by these laboratories, though of substancial nature,has hardly touched the fringes of the whole problem. In fact, investigations carried out so far have opened new avenues. One of the most important findings has been the relation between soil and weather conditions on the nutritive value of grasses and other feeds. India possesses a variety of the soil and environmental conditions and the nutritive value of a particular fodder grown under certain conditions may differ widely from that of the same crop in another part of the country under different soil-weather complex. Different breeds of cattle react differently under altered conditions,[48] so that the physiological responses of the various breeds towards changes in temperature and humidity have got to be carefully studied and suitable rations have to be formulated for such conditions. India possesses a large variety of grasses, the nutritive value of many of them is still unknown. Besides, feeding value of such grasses at different stages of maturity differ widely, so that, such investigations will be useful in determining the maximum quantity of different nutrients which may be made available per acre in different parts of India through such forages. New sources of feeds from un-organized sources may also be discovered if country wide search is made.

In carrying out these investigations, only one Division at Izatnagar and three small sized laboratories which are now functioning in different parts of India are not sufficient. In U.S.A. where the cattle population is much smaller than in India, each state has an Agricultural Experiment Station, in each of which there is an Animal Nutrition Division. Each such division employs from 10-50 research workers, besides a host of Extension officers. Moreover, in every university in that country fundamental researches on animal nutrition are being carried out and the researches on physics, chemistry, biochemistry, animal husbandry, dairy, genetics, zoology and physiology sections are being freely drawn upon.

On this basis it is urged that there should be one Animal Nutrition Research Station opened in each state of India, and Animal nutrition should be taught as a separate subject in each Veterinary and Agricultural College. I presume Veterinary College Mathura is the only one of its kind to have Animal nutrition as a full course subject. This is due to the keen farsightedness of the progressive State Govt. and Dr. R. L. Kaura, Director, Animal Husbandry of Uttar Pradesh. The I.C.A.R., being alive to the importance of zonal problems has decided to establish 3 Regional Animal Nutrition Research Stations i.e. for West India at Anand; for South India at Bangalore and for the East in Calcutta or Cuttcck. The addition of one more station for studying the problem of livestock of the temperate climate is also highly desirable.

The co-ordinate the work of the whole Union and also to conduct work of fundamental importance a strong Central Animal Nutrition Research Institute, as originally recommended by the Royal Commission on Agricultural Research should be established. This Institute should establish a close liasion between the animal and human nutrition workers on the one hand and medical, veterinary, agricultural and forest departments on the other hand. It will be the duty of the nutrition department in each state to advise the agricultural department how best to increase both human and animal nutrients by proper allocation of land under the most effective rotational and cropping methods.

It is surprising that private enterprise does not come forward in India for organizing research. If we examine the total expenditure in the 8 States

of the Union, of which statistical data is available, it is found that out of a total expense of 292 crores only 3.2 crores are spent on Veterinary and Animal Husbandry Department. This comes to 1.1 per cent of the total expenditure, as is shown in Table IV.

TABLE IV

SHOWING TOTAL EXPENDITURE OF SOME STATES OF THE UNION IN RELATION TO EXPENDITURE ON ANIMAL HUSBANDRY

State	Total expenditure	Expenditure on Veterinary & Animal Husbandry Deptts	Percentage
Assam	10,21,45,000	6,70,000	0.66
Bihar	31,13,00,000	23,76,000	0.76
Bombay	60,59,73,000	51,23,000	0.48
Madhya Pradesh	20,30,60,000	32,41,000	1.60
Madras	62,25,66,400	57,10,000	0.92
Punjab	16,84,38,000	23,53,000	1.40
Uttar Pradesh	52,21,11,700	1,09,93,800	2.10
West Bengal	38,80,74,000	17,92,000	0.46
	2,92,36,68,100	3,22,58,800	

Further a close examination of the returns from land revenue of these 8 states and the percentage of money spent on Veterinary and animal husbandry department reveals some interesting facts as are given in Tavle V.

TABLE V

SHOWING TOTAL LAND REVENUE AND ITS PERCENTAGE SPENT ON ANIMAL HUSBANDRY

State	Land revenue	Percentage spent on veterinary and animal husbandry department
Assam	1,68,07,000	3.99
Bihar	1,44,90,000	16.40
Bombay	6,60,97,000	7.74
Madhya Pradesh	4,04,58,000	8.01
Punjab	1,69,28,000	13.90
Uttar Pradesh	7,30,99,500	15.03
West Bengal	2,08,18,000	8.60

The total livestock population in these states is about 25 crores. Whereas, the income per head of livestock comes to Rs. 77-6-0. the expenditure per head is only 19 pies.

If, however, the money spent on Animal Nutrition research is calculated on an All India basis it comes to as low a figures as 1/5th of a pie

per animal per annum. The magnitude of the problem can further be gauged when it is noticed that one trained research worker in animal nutrition is available for 6 million heads of livestock.

Closer link between laboratory and field

In order to convey the findings of the laboratory to the field the existence of an Extension Service is essential, so that through bulletins, lectures and more particularly by demonstration in farms, conservation of feeds and utility of correct feeding and their ultimate effect on the health and productivity of livestock may be brought home to the livestock owners throughout the length and breadth of the country.

Recently a step towards this direction has been taken by the I.C.A.R. by recommending the appointment of an Animal Nutrition Extension officer who will be attached to the Community Projects and Key Village Schemes.

Fortunately under the present constitution, an effective method of starting work at the village level exists in the "Panchayat system". The panchayats of a number of villages can be taken round Government farms to show the work there and they may be asked to send some intelligent farmers from their villages who can be taught the practice of scientific feeding. These workers can then go back to their villages and can demonstrate the efficiency of balanced feeding which practised on a large scale has given interesting and satisfactory results in Orissa. Co-operative societies opened in villages can help villagers in getting seeds of fodder crops, and concentrates at cheaper rates and can also help them in marketing the surplus milk, ghee, eggs and meat.

To sum up, we find that as conditions exist to-day the nutritional status of both man and livestock is poor in this country. The condition of livestock is much worse and viewed in the light of age old customs of Indian food habbits and agricultural operations, no substantial improvement in the nutritional well being of the man can take place unless the betterment of our livestock is achieved. The first step in this direction is a supply of an adequate ration to all types of livestock. The long gap between the target to be aimed at and the present availability has been brought out and has been shown how this can be narrowed if efforts are made to utilize all the feeds— available from the organized as well as from sources which are, at present, not being exploited. Further research on finding better types of livestock forages, improvement in methods of conservation and more intensive search for newer types of feeds will help substantially to raise the nutritional status of livestock, especially cattle. In long term policies, some of the arable land should be set apart for fodder production and sound rotational cropping system will prevent any loss in the production of cereal grains. It is essential also that the help of other sciences viz. Physics, Chemistry, Biology, engineering etc. may be requisitioned to augment the food production in the country.

The remedy to meet shortages is to grow more food. But in doing so three objectives must essentially be kept in view in planning the reorientation of the country's food supply Firstly, adequate supply of calories, secondly, liberal supplies of "protective foods" like milk, milk products and fresh vegetables and thirdly the diet should provide a reasonable range of variety.

It is strongly felt that with a proper reorientation in the pattern of land usage, and improved livestock the nutritional value of our diet and thereby the health of the nation will undoubtedly improve.

Last but the most important part in any scheme of national importante is the role played by the enthusiasm and support of the general public. This support is all the more needed in livestock improvement policy, as livestock industry is essentially a cottage industry and is diffused throughout the length and breadth of the country embracing the tiniest village in the Union. The public is to be educated by all types of propaganda about the vital role of livestock, particularly cattle in the general welfare of the country and its people. I may suggest that if we are to be made an animal minded nation special attention should be given to the propaganda among boys and girls who are the citizens of tomorrow. We may take a tip from the U.S.A. where clubs like 4-H clubs are helping in teaching the rudiments of animal husbandry to the young generation. In these clubs, of which there is practically one in every hemlet boys and girls are encouraged to raise livestock like dairy cattle and poultry etc. in community farms of their own. Thus a thing which starts as a hobby may set a boy into the path leading to the establishment of a dairy or a poultry farm. In our villages also such clubs can be attached to every school where the A,B,C, of practical agriculture and animal husbandry on modern lines can be picked by teen-aged youngesters In this way the cow can be lifted from its down-trodden condition of to-day and placed in the eminence, which time-old experience has assigned to it in our country.

It is hoped that the brief review of experimental evidence on the influence of adequately feed livestock on the food production and general nutritional level of human beings will stimulate thought of leaders in the domian of animal husbandry, agriculture, forestry and medicine and of the authorities concerned, so that no time is lost in undertaking exhaustive studies of the problems raised, the partial or complete solution of which will contribute towards bringing about more efficient livestock production resulting in meeting fully the man's needs for animal products.

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SECTION OF PSYCHOLOGY & EDUCATIONAL SCIENCE

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Presidential Address

GROUP-INVOLVEMENT IN THE CAUSATION OF GROUP TENSION

INTRODUCTION

I am deeply sensible of the honour done to me in your having elected me President of this section. I feel much obliged to the Indian Science Congress Association, and particularly to my colleagues of this section.

During recent investigations various causes of inter-group tension, such as, psychological, social, economic, political and historical have been discussed. The basic ones are those which depend upon how we perceive and judge social situations, what we expect out of them, and how they affect our interests and purposes. It is well-known that the feeling of belongingness to our own particular group, combined with that of separateness and difference from other groups, constitutes a very important set of factors which determine our perception and judgement of a social situation and the expectancies from it. It has both a positive and a negative aspect corresponding to the in-group and the outgroup. This feeling has usually been named in a loose and vague manner as class consciousness. But this term Is not expressive of the dynamism involved in the functioning of the phenomenon. The feeling of an individual that because he belongs to a particular group, for example, a religion, a nation, a caste, a province, a race etc., he should expect advantage from his in-grouper and harm from the outgrouper, is not merely a consciousness of his class, but something definitely more than that. Class consciousness, on R. Center's own showing, is not a psychological reality in the functional sense, unless the members have common interests and outlook, are bound by their feeling of belongingness and loyalty to their class, and are aware of the hostility of its interest to those of other classes. (4. Chap. II). It may therefore be designated as the feeling of group-relations. The object of this paper is to put forward the view that the feeling of group-involvement is the basic cause of inter-group tension, and that social distance, stereotypes, prejudice etc., which characterise every heirarchical and competitive form of society, may not necessarily function and cause tension, unless motivated by the feeling of group-involvement.

GROUP INVOLVEMENT AND EGO-INVOLVEMENT

These two concepts would appear to be closely connected. An individual is judged by others from two separate perspectives or frames of reference. He is judged to have certain characteristics either solely as an individual on the basis of his personal merits and demerits, or on the basis of the

characteristics of his group, especially if he is not sufficiently known through personal contact. In the former case, he is not labelled or categorised, while in the latter case, he is labelled and categorised ordinarily in terms of the stereotypes attaching to his group. In the former case, other persons' judgement would make him relatively more ego-involved, while in the latter case it would make him group-involved. Accordingly the structures at the basis of ego-involvement and those at the basis of group-involvement would appear to differ in certain important respects. In the former case, the attitudes are with the ego as the centre, ego-centric, but in the latter case, with the group as the centre, socio-centric. All the members of one's own group, with the attitudes norms and values of the group are incorporated into a "me" and make for ego-involvement, so that when his group is insulted, he feels insulted. In the case of group-involvement both the other members and the "me" are incorporated into a common and collective "we", so that when he is insulted he feels that his group is insulted. It would thus appear that there is a significant difference between the two, at least of accentuation or emphasis, denoted by 'me' and 'we' delineations in social thinking and behaviour.

But there are two points to be emphasised in this connection:

(1) There is an essential core of individuality in the ego, by virtue of which the ego is not merely "the social in man" not merely a version of the group. Whatever is interiorized in the ego may not all be adopted as its own in the intimate and personal sense. It may even clash with the ego's own goal as an external imposition. Lewin and Lippitt have drawn a distinction in connection with group-goal-involvement between one's own goal and group goal, and found, on the basis of experiments, that although both the goals are interiorized in the ego, a clash between the two may, and, does occur. This envisages the probability that in some situations at least, the individual may be able to transcend his narrow group norm, show his independence of spirit, form his own unprejudiced judgements, and even revolt against his own group.

(2) But in group-involvement, the core of individuality in the ego has ceased to function,—the self is overwhelmed by the collective image of of his own group, and the possibility of disagreeing with his fellows does not exist. In short, the ego-involved individual still retains his capacity to make impartial judgements, while the group-involved person does not.

Socialisation

Group involvement is an attitude and frame of reference towards one's own group and also out-groups. It is acquired under the process of socialisation, which takes place in a person's own socio-cultural group. Now, if a group is completely homogeneous, having no sub-cultural areas, nor differentiated sub-groups, there is no inter-group, tension or hostility, even though there may be inter-personal hostilities within it. Again, if two such groups live in their respective territories without communication with each other, and in isolation no inter-group relation or tension is possible. But the moment they come in contact, or when they get differentiated into sub-groups, the possibility of tension arises. The primary condition of tension lies in the context of intercommunication and inter-action, specially when both are involved competitively in the same situation. The crux of the whole question is as to how the pattern of inter-communication and inter-action develops between the groups. But since a group in modern times does not live an

isolated life, but in a larger field of multiple groups within a nation (or one nation in an international field), some pattern for group inter-relationship must structurise for inter-group adjustemnts. A standard of reference for such structurisation is required The social distance and stereotypes prevaling in the group provide the standard. At the root, however, is the group's own image of self which as recent researches have shown, is invariably self-flattering. The researchess of W. Buchanan (2. p. 522) on stereotypes reveal that there is a "universal tendency to appropriate the complementary adjectives for one's own countrymen", Studies of social distance scale in America have shown that if another nation matches the self-image, it is held at the top of the scale. That is how the Americans accept, the Canadians and the English to be more intimate to them than everyother nation. To the extent that an out-group matches or does not match,t he collective self-image, it is held to be good and friendly or bad and hostile. Intergroup relations structurise generally in the context of a dichotomous pattern of such a "we-and-they" relations. The flattering self-image of one's own group and its "similars" are good and give protection and security. But images of out-groups are indifferent, or bad and constitute a threat to security. It appears that this sort of social tlinking and judgment follow along clear-cut concepts so that groups are regarded as either good and friendly or bad and hostile. All goodness and friendliness are drafted away by the collective self-image of the in-group and its similars, whie badness and hostility remain the characteristics of the dissimilar groups.

Social Perception

The question of inter-group relation is based fundamentally on how we see others and how others see us. This is the question of social perception in inter-group situations. Social perception is inter-personal, in which at least two persons of the same, or of different groups inter-act. This at once shows the importance of two things, viz., (1) communication between the two (2) expectancies of each about the other's reactions. The roles of these two processess in social relations have been rather neglected, and require to be fully explored. I shall have to say something pressently about these two.

Taking the instance of an out-grouper as the other party in a social situation, the perception of him would naturally take place in terms of the social or frames of reference acquired in one's own socio cultural group. Recent cross cultural studies carried on intensively by anthropologists have shown that as a result of socialization, individuals are 'prepared' to perceive, expect, and think in ways determined by their respective social norm and values. Experimental studies carried on by psychologists during recent years conclusivly agree in showing that attitudes and frames of reference, congruent with the differential culture patterns of different groups are developed, and provide individuals with common and "shared" norms for perceiving and judging things and persons. The first thing which therefore appears to happen in this kind of inter-personal contact is that the out-grouper must be categorised in terms of the social norms of the perceiver. As a matter of fact each would proceed in his mind to categories the other. In a heterogeneous society composed of multiple sub-groups, particularly in a cast-ridden society like ours, this is bound to happen. With categorisation, the door is opened for stereotypes, prejudices, feelings of dominance or submissiveness etc., to enter and influence that process of perception. Often mere naming of persons is sufficient to categories them. Proper names

in India are indicative of castes. Razrau's experiments on "Ethnic Dislikes and Stereotypes", reported by Otto Klineberg (5. p. 507) demonstrate how social norms, such as stereotypes, affect perceptions. A number of photographs of girls was shown to a group of college students who were asked to rank them for beauty, intelligence, character etc. Two months later the subjects were shown the same photographs with Jewish, Italian and Irish surnames etc. added to the photographs. The addition of the surnames now changed their previous ranking in terms of the stereotypes associated with these ethnic groups. This shows that categorisation by naming had definitely affected the perceptions of the subjects. Their perceptions changed from seeing individual characteristics to seeing group characteristics.

The prejudiced person is somehow incapable of discrimination, because he always categorizes the out-grouper. His frame of reference makes him selectively inattentive to individual characteristics. Selective inattention is to oversight or negligent observation, but the result of the functioning of prejudice. All port referf Seleman's study which "shows how peoples power to recognize individual Negro faces varies inversely with their anti-Negro prejudice. (1. p. 10).

It seems, therefore, that impartiality in perceiving, judging, expecting etc., in complete freedom from pre-determination by social norms and entirely on the basis of individual and objective characteristics of a person, is illusory in psychology This, of course, does not mean that a person is incapable of judging anyone rightly and disinterestedly. He can do so provided he can control his own ego and group involvements, and delay his judgements and expectancies until the relevant facts are available.

Communications

It was just hinted above that social perception depends upon communication. Newcomb has suggested that "Social psychological problems must be attached in terms of communications processes". (8. p. 42). We will discuss communication between members of opposed or different groups, as distinguished from communication within a group. Inter-personal contact leads to a kind of communication which initially takes place under the influence of the respective attitudes with which each approaches the other. Each party has its stereotypes and artistic group norms in regard to the other. The inter-communication has, therefore, to be assumed to proceed in this context. Newcomb writes, "One important aspect of inter-communication has to do with the effects upon members of one group of their perception of the behaviour of members of another group. With rare exceptions, every individual perceives the behaviour of an out-group member in terms of his own group's social norms" (8. pp. 41-42). In other words, the out-grouper's behaviour is usually perceived in terms of what he has learned about the characteristics of the out-grouper. But, it should be added that the contact provides good opportunity for mutual check-up of their stereotypes, and prejudice, and reduction of inter-personal social distance. But recent experimental findings on the result of personal contact between foreigners show that in the majority of cases, though not in all, new experience and personal contact even if satisfying are not adequate to remove or even reduce prejudices. When G. W. Allport writes "It was prejudice when the Oxford student remarked that he despised all Americans but had never met one that he did not like" (1. p. 6). It showed that inspite of satisfying contact, prejudices remained unaffected. The subjective

group involved attitudes and frames of reference are so strong and obstinate that unless they are initially relaxed, new contact fails to reduce them.

One of the most common causes of misunderstanding is a literal lack of understanding of the meanings of propositions communicated by one to the other. The communicative process has to do, to quote Newcomb again, "With the perceived overlap between the communicating individuals. That is, what is expressed by each to the others, and what is received by each from the others, is (hypothetically) a function of what is perceived by each to be the area of shared perception" (8. p. 47). But the sharing of perceptions becomes difficult if each party approaches the other with his respective group.—autisms. It is really very surprising to see the difference between what you actually say, and what has been recorded by listeners and members of an audience. And when it comes to reporting some more distortions take place.Experimental research is required to settle how far pre-dispositions, stereotypes and similar other autisms, which make a person "insular" to his own group are responsible for misunderstandings. Basic research in the psychology of communication is more urgently required, not only for the study of social psychological problems in general but also off tensions in particular. A host of problems exist. For instance, take the question of accuracy of communication in respect of situations where only "things" are concerned, and compare it with those where persons, specially of a hostile group, are concerned. The comparative measurement in the two cases will very probably show that accuracy in communication about persons will be less than about things and physical events.

One thing is worthy of note where persons of different groups face one another in a communicative situation. Open expression of prejudice may be inhibited G. W. Allport mentions the researches of Robinson and Rhode who found that interviewers who appeared to be Jews, on introduced themselves with Jewish names "obtained far less open expression of anti-semitism than did interviewers who seemed to the respondents to be non-Jewish" (1. p. 18). It is difficult to be sure whether in such contact situations, the participants react intra-mentally to their prejudices as anti-social or unable. At least, they do not like to be disagreeable. In any case, the possibility of dissolving stereo types and prejudices through increased inter-group contact should be experimentally explored more systematically than ever before.

Expectancy

Just as communication determines social perception, expectancy also does the same, and structurises the situation in further definite ways. Expectation of what the out-grouper may be going to do is bound to influence my own perception of him. Expectancies are usually integrated into group attitudes in ways congruent with the attitudes. As a consequence, my expectancy of his behaviour would be influenced by the stereotypes and prejudices which I have learned to attribute to his group.

Thus he would be perceived and judged to have no independent personality traits and qualifications except those which follow from the characteristics of his group. My opinion of him and my expectations about him would be the same as are held by the rest of my in-group members. It seems as though in such a social situation, it is not that one individual being confronts another individual being, but their respective group-images. Such expectancies of the behaviour of the out-grouper implies, therefore, my own involvement with my group. Expectancies dictated under such group

involvement feelings may thereby cause misunderstanding, or at least, lack of proper understanding, of the other fellows' attitudes, and make me suspicious of him.

Expectancies of the behaviour of out-groupers are also generally manipulated and channelised by various agencies within the in-group they suggest the requisite frames of reference. If the frame of reference makes you perceive an out-sider as undersirable or hostile, you should expect him to behave in undersirable and hostile ways. As mentioned above, a well-defined frame of reference for perception makes a person autonomously integrate with it such expectancies as are congruent with the frame of reference. Action may then be left to follow upon the expectancies. Therefore one of the methods of publicity, propaganda, and leadership suggestion etc. is just to define or change people's frame of reference about situations, persons, or groups, and leave it to the people to develop appropriate expectancies and behaviour.

Some important Theories of Inter-group tension

We have now seen that social perceptions in inter-group situations are usually determined by the group autisms of each participant so that neither the one nor the other is capable of understanding each other in a way that two in-groupers know and understand each other. In a heriarchical and competitive society, with many different sub-groups such as castes, religious groups, social classes etc.' scales of social distance, stereotypes and prejudice inevitably exist, and determine perceptions and expectancies. They undoubtedly provide the background for inter-group tension. But such tension need not actually arise merely because they exist. The stereotypes and prejudices etc. may be just merely sociocultural or traditional patterns of conformity. Indeed with most people they are so, with the exception of certain types of character structure or personality such as, the authoritarian, the conservative, the deeply insecure and anxious etc. If they are regarded as sheer conformity patterns, they do not possess any motivational or functional significance. They may however, acquire motivational power under conditions of group-involvement. But there are a number of approaches to the problem of group tension. It will be useful to survey them as briefly as possible.

Broadly speaking, there are three such approaches: (1) The psychodynamic approach of which psychiatrists and abnormal psychologists are the chief exponents. The fundamental stand they take is that intra-psychic and repressed aggression produces tension in the individual, and that this tension is projected or displaced upon out-groups. Stereotypes, prejudice etc. are regarded as socially permissive channels for the discharge of such repressed aggression. These patterns would thus seem to possess motivational power from the very outset. It is further assumed that every individual for the sake of his own internal peace of mind, and relief from anxiety and insecurity must discharge his aggression along the lines of stereotypes and prejudices etc. upon the out-group as a whole. Group tension would therefore be a sort of collection of individual tensions. This is, however, an extreme view. Eysenck warms against the insistance on unconscious motivation, and about the nature and derivation of aggression on the basis of the "extremely subjective interpretations given by a number of psycho-analysis of the dream, free association and other productions of their patients, who cannot by any stretch of the imagination be called a prepresentative sample of the normal adult population" (7.p. 50) He also observes

that "the tendency in social psychology to look for unconscious processes and rationalisation in relation to all social thinking is open to criticism". (7.p. 64)

The psycho-dynamic view necessarily requires scapegoating the out-grouper. Zawadski, writing on the "Limitations of the Scapegoat Theory of Prejudice" (10. p. 43) and Lindzey in his "Experimental Examination of the Scapegoat Theory" (same journal 1950, 42), have shown that the theory of displacement is not adequate to serve as an explanation of prejudice. Further, it is not very clear how the passage from individual tensions to group tensions is effected. The only answer to this question is the analogy of the steamboiler containing various channels, or safety-values for the escape of steam power. It is undoubtedly true that repeated frustration and accumulated aggression would produce changes in personality structures, making the person irritable, unstable, anxiety-ridden and authoritarian. But this does not answer the question how each and every individual of a group developes the same personality types. Further the theory of accumulated aggression with the necessity for its displacement to out-groupers is, in effect, hardly different from the theory of an original instanct of aggression, and is full of dangerous consequences of the need for outlet and the justification, and rationalisation of such a need. Finally, sociologists rightly criticize such a purely psychological and personal theory of inter-group tension as containing the danger of "psychologism", because it ignores the importance of social realities and situations in causing the tension. For instance, it is well-known that stereotypes change with situations. Reference may be made to a number of studies reported by Otto Kilneberg in his paper on "National Stereotypes" (5. p. 509) Shrieke's study of the Chinese in California shows that when the Chinese were in great demand for certain types of occupation into California, they were described as thrifty, sober, law-abiding, in-offesive etc. But when the economic situation had so changed that other groups were into competition with the Chinese, the stereotype about the Chinese changed to clannish criminal, debased and servile. Again Meene's study showed that the American stereotypes regarding the Japanese and the Germans changed from favourable to unfavourable with the outbreak of World War II. G. W. Allport makes the observation that "when the Russians were allies of the Americans in war-time, they were readily perceived as courageous cheerful, progressive and liberty-loving people. When in the post-war period circumstances had shifted, the image became one of a cruel, oppressed, atheistic and double-dealing folk" (3. p. 62).

2. The social-psychological approach pioneered by Sherif and Cantril:- Group tension is due to the clash between the norms of one group and those of another. Group prejudice as a social norm, is acquired just as a person acquires his identifications, values, and loyalties. "In order to be a good member of the group" writes Sherif, "he has to share these prejudices as well as other values of his group—positive and negative" (9. p. 340). It is an aspect of the ego development through family influence and other social pressures. In course of time such social influences are forgotten, and the norms become completely interiorised in the ego as part of the constellation of attitudes of which the ego is composed. The norms are no longer merely of the group,—they have become his own. The social distance prevailing in the structure of a group may, therefore, be expressed as ego-distance. The motivational power of the prejudice is, drawn directly from ego attitudes. It is unnecessary to assume repressed aggression in the individual and its displacement to be at the root of prejudice.

This approach appears to be more acceptable than the purely psycho-dynamic one. It takes full account of the social aspects of the origin of prejudice. But it seems to leave no margin for the individual to exercise his individuality independently of the social norms he has acquired. The ego is made almost completely a version of the group,—merely a receptacle which has been filled by the in-take of group culture. But it is a matter of common observation that inspite of the introception of group norms, an individual may not have accepted all in the truly functional sense, so that he is still capable of taking a detached and impartial view of others, and of behaving in ways contrary to the norms acquired by him. The motivational aspect remains rather weak, and insufficiently defined.

3. The third approach may be said to be that of G. W. Allport who combines the psycho-dynamic and social approaches, as presented by him in his contribution on "The Role of Expectancy" in the book called "Tensions That Cause Wars"[3]. He insists that both personal and social factors are involved in group tension, and it is futile to argue which is the basic. He says that so far as "immediate" causation is concerned, the psycho-dynamic factors are important, and for "long-run" causation the social, historical, and economic influences of a social system are often decisive. In this view the motivation is taken from personal, psycho-dynamic factors, and it is linked-up with the prevailing group norms, stereotypes, prejudices, etc. by the process of channelling through traditions, symbols, and the influence of parents and leaders etc. Accordingly his view of prejudice is that it implies categorisation, displacement and rationalisation.

Allport's approach is comprehensive. I have only one remark to make. According to his view, inter-group antagonism would be more an expression of individual psycho-dynamic factors than a matter of social causation, because the source of the motivation is held to be individual psycho-dynamics. He, therefore, writes of channelising of individual hatred upon substitute objects. This would naturally imply that stereotypes, prejudices etc. provide outlets for the relief of inner tension, anxiety, and insecurity. It is, however, quite likely that channelised hatred etc. may still leave to the individual a margin for some independence of outlook, which Allport does not deny to individuals on account of their uniqueness. Many individuals feel, in their cooler moments, that prejudice is irrational and unjustifiable, —some people even condemn it openly. Provincialism casteism, communalism etc. have been repeatedly condemned from the platform. These things imply that some independence and critical power of appraisement is still left. But when the same persons in their actual conduct fall victims to the prejudices they condemn, then 'something' has happened in their minds, —independence of judgement has been lost, and some other frame of reference has come into operation. Our own view is that this 'something' is involvement with their group that has now come in to activate their prejudices.

Causation of Inter-group Tension

According to the view taken here the established scales of social distance, prejudice and similar other group norms are patterns of conformity behaviour. They do not possess motivational power from the outset. As already pointed out they are unavoidable in a heirarchical society consisting of various sub-groups and organised on a competitive pattern. Normally and in everyday situation, they do not seem to function except as

inducements for avoiding certain classes or groups. They are not a sort of standing incitation to exercise hostility against outgroups. There is a large difference in degree from mere avaidance to antagonism and hostility. Inter-group tension in the sense of active conflict cannot therefore be regarded as the result merely of the categorization of the out-grouper, through the established scales of social distance, stereotypes, prejudices and similar other group norms. Some additional factors must be assumed to function in intensifying the avoidant attitude into well-defined tension and hostility.

Now it is through the medium of competitive and frustrating situation that the new factor of group involvement comes in. The social-psychological significance of such competitive situations consists in the fact that two groups, more or less directly concerned in the situation now align themselves in definitely conflicting camps. Each group's feeling is intensified with the perception that the other is a rival, and the expectancy that its behaviour will frust its interests and purposes. Their respective social perceptions of each other has now changed, as for instance of the Chinese in California in Shriek's study quoted above which demonstrated that with economic changes in the situation they came to be regarded as criminal, debased and service. The in-group members develop a positive attitude of closer identification, solidarity and cohesiveness among themselves, along with more well-defined antagonism against the competing out-group. This is supported by an observation made by Sherif in his "Experimental Study of Inter-group Relations" he says, "In brief the consequences of the intergroup relations in competitive situations and in frustrating situation which members of one group perceive as coming from the other group; (i) to solidify the in-group belongingness and solidarity, to enhance in group democracy and to strengthen in-group friendships: (ii) to generate and increase out-group hostility, to produce derogatory namecalling which came close to standardising of negative stereotypes in relation to the out-group (i.e. rudiments of prejudice) (8. p. 420). Even if groups as such are not directly involved in the competition, but only individual members, the same thing would happen, because the members carry the collective images and norms of their respective groups, and are expected to cause the same frustrations. A remark made by G. W. Allport, reporting some important findings of sociologists, is also relevant to our purpose. He says, "Even a differentiated society does not generate acute inter-group hostility unless there is possible up-ward mobility within the social structure. The more numerous the members in an upwardly mobile minority group, the greater the prejudice against them" (1. p. 20). Prejudice shoots up against upwardly mobile monority groups obviously because of the group-involvement feelings of the rival groups released by the competitiveness involved in upward social mobility of these minority groups which stand low in the social and economic structure. In such a state of affairs the irrationality of prejudice becomes more evident due to the group-involvement feeling that the out-group is definitely harmful and hostile. Instead of assuming that accumulated and repressed aggression with its displacement explains the irrationality of prejudice(Dollard), we may assume, on social psychological grounds, that group involvement is responsible for the same.

Newcomb's Bennington, study as reported by Sherif[9] may also be referred to in support of the importance of group-involvement. One of his important findings is that information about contact with and the new experience of the outgrouper are not sufficient to change prejudiced attitude because there is a strong linkage between belongingness with one's group

and the acceptance of the group's attitudes and values. New knowledge and experience can function only when they are linked-up with the acceptance of new group as the reference group. The acquisition of a new attitude is a function of relating oneself positively to some new group, and at the same time of relating oneself negatively to the group which inculcates the old stereotypes and prejudices.

Conclution

To conclude, the concept of group-involvement has been presented in a tentative form for what it is worth. Its validity as an explanatory principle of social conflicts would depend upon experimental exploration and field observation. For instance, persons may be tested for their high group-involvement and there stereotypes and prejudices against out-groups. If a positive co-relation can be found between group-involvement and group prejudices, the concept would acquire definite significance as an explanatory principle. It is my belief that if the range of group-involvement, such as caste and provincial involvements, is widened from its narrow concentration to more broad based indentification with the nation as a whole,—and from the national to the inter-national field, i.e. to new and wider reference groups'—a great many projudices would either be resolved, or prevented from functioning. Consequently group tension would also be either reduced, or prevented from causing actual social conflicts.

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SECTION OF ENGINEERING & METALLURGY

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Presidential Address

COAL AND THE ENGINEER

I sincerely thank you for electing me the President of the Engineering & Metallurgy Section of the Indian Science Congress Association for its 40th Annual Session at Lucknow. I am extremely grateful for the honour you chose to bestow upon me. I take it as an honour to the profession I happen to belong to, (i.e.) Fuel Technology and Chemical Engineering. I hope, I shall be able to live up to the high standard for this exalted office set by my illustrious predecessors in the past. There is little doubt that your willing co-operation and help will render my task easy and the current session of our section will meet with the same amount of success as in the past.

INTRDUCTION

It should be clear from the Abstracts of Papers to be read and discussed before this Section, already published, that they cover a wide field, and Engineers, Technicians and Scientists engaged in various spheres of activity in Engineering and Technology at different centres in the country are taking keen interest in developing this comparatively young section of the Association. The learned President last year decided to speak on Technical Education while delivering his illuminating Presidential Address. The importance of the subject with respect to our national requirement may be judged from the fact that yet another worthy President in the recent past chose the same theme for his Presidential Address.

At the monent, our Coal resources, more particularly our resources of Coal suitable for metallurgical purposes and the question of their conservation are drawing a good deal of attention and causing much anxiety and concern to those engaged in its winning and utilisation. It is hardly necessary for me to stress upon the importance of Coal to Engineers and Technologists. We may say, as it was said by an Englishman as early as 1865, in his anxiety to conserve the Coal resources of his country that "Coal in truth stands not beside, but entirely above, all other commodities. It is the material source of energy of the country—the universal aid, the factor in everything we do. With Coal almost any feat is possible or easy; without it we are thrown back into the laborious poverty of early times...... The progress of Science and the improvement in the Arts, will tend to increase the supremacy of steam and coal. The more economy that is practised in the use of Coal the more will its consumption increase, for economy multiplies the value and efficiency of our chief material; it indefinitely increases our wealth and means of subsistence and leads to an extention of our population, work and commerce, which is gratifying in the present, but must lead to an

earlier end. Economic inventions are what one should look forward to, likely to continue the rate of increasing consumption. Could we keep them to ourselves, indeed, they would enable us for a time, to neutralise the evils of dearness when Coal begins to be scarce, to keep our accustomed efficiency and push down our coal shafts as before. But the end would only thus be hastened— the exhaustion of our seams more rapidly carried out."

In spite of this early warning, it has not been possible either to reduce the coal output or to restrict its consumption in this leading coal producing country; on the other hand, during the subsequent years, both have steadily gone up enormously, and lately strenuous efforts are being made to increase the output still further to meet urgent demands, so that, import of Coal may be stopped. Indeed, the position is such that England is surprised to find hereself importing Coal from outside. Even an insignificant coal producing coutry like India had occasions to export Coal to the United Kingdom. Britain finds that she can no longer count upon her best resources of high grade coal which are now much depleted due to extraction during the past century and a half and she must try to do the best with what she is left with. Of necessity, she has been compelled to adopt the wise policy of prevention of avoidable losses during extraction and use. The most important aspect of the Coal question is not so much how long can the reserves possibly last,—but how long can the country continue to get the available coal at a cost which shall not place the nation at a disadvantage to the nearest competitors. It is considered that the object of any national movement in the direction of fuel economy should be to ensure Coal being utilised, in the national interest, to the fullest advantage by every class of consumer. True economy lies not so much in using sparingly as in using well. Negative neasures are of doubtful value and ultimately lead to self-destruction. It is this aspect of the problem, (i.e.) utilisation of coal resources in national interest that I am anxious to deal with in my Address, and I crave your indulgence to permit me to do so. Since the past few years, the Coal problem of the country has become so acute that its various aspects have been affecting industry and the people of our country seriously. The quality of Coal is no longer as good and its price as reasonable as in the past and its supply is subject to baffling restrictions. The Government is being advised and driven to take such measures as it is seriously apprehended, will ultimately defeat the very object in view. At this juncture, it is for the Engineers and Technologists to come forward with helpful and constructive suggestions to save the situation. Before proceeding any further I find it necessary to present a short historical back-ground of the development and progress of the coal mining industry in this country and I hope, you will please bear with me patiently for a while.

Foot Falls of the coal mining Industry

The development of the Indian Coal Industry is a romantic aspect of the industrialisation of this country. Though the word "Coal" does not occur in our ancient Indian Literature, it is apparent from outcrop of fires in the Damuda Valley Coalfields and knowledge of the people who inhabited these tracts that Coal was known in India from time immemorial. But lack of interest in its development and actual mining operations was due to the fact that in ancient times wood was abundant and human needs were few. True to human nature people followed the path of least resistance, and did not care to undertake the arduous job of mining Coal even if they were aware of its existence. We have it from history that Coal was neither mined nor traded in until John Summer and Suetonis Grant Heatley discovered it in

Bengal in 1774, and applied to Warren Hastings for permission to start coal mines. However, actual mining operations did not commence till the year 1815, when Mr. Rupert Jones, who was sent out from England to explore the possibilities of the Bengal Coalfields, discovered the coal seams at Raniganj.

The said discovery changed the history of that large tract of land known as the coalfields of Bengal and Chotanagpur. Gradually a number of firms and individual enterprisers started mining operations but actually not much work was done until 1843, when the two leading firms were amalgamated and the Bengal Coal Company was formed. With the inception of this new firm, some other firms also began to work coal mines in the neighbourhood of Raniganj. These pioneers in the coal industry were, however, faced with the difficulties of easy means of transport, as they had to use boats for floating down the Damodar with their cargoes to the Ganges and this only means of communication could be availed of only during the rainy season.

The opening of the East Indian Railways in 1855 and its extension to the Burraker coal areas in 1865 gave a fresh impetus to the collieries by removing the transport difficulties. The coal industry in India, it may be said, practically owes its origin to the construction of railways in this country which not only led to easy means of communication, but at once created a large demand for coal. The search by the East Indian Railway Company for a cheaper and more accessible supply of coal than the imported British coal led to the development of the Indian coal industry by a number of Joint-Stock Companies. In the year 1865, the Equitable Company was floated. In about 12 years, one more big coal company and the Burraker Coal Co. came into existence. However, the existence of all such large concerns, coupled with many other private collieries, failed to increase the coal output of the country to any appreciable extent. In 1872 the Bengal Coalfields were producing only 322443 tons of coal agaist 216580 tons in 1858. In 1878-80 the average Indian coal output was 987000 tons. In the next five years the average reached the figure of 1225000 tons. The low output was due to various causes;—a number of collieries were still far away from Railway lines and had to bring their machineries by the slowest mode of transport (bullock carts), immense labour was involved in carrying heavy boilers, etc., over a country without good roads, on bridgeless brooks full of water, the carting was held up for days together, even the collieries which were on the Railway lines were faced with unsympathetic Railway officials who did not like to increase traffic by granting resonable transport facilities to the collieries, if the collieries were to be provided with sidings, they were required to pay in full for their construction and maintenance,— under such circumstances, it was no wonder if the development of the coal industry was very slow till the nineties of the last century. Besides the difficulties of transport, there were other hurdles in the way. The collieries at that time were not properly equipped; sinking operations were primitive, the method of working was wasteful, the appliances and method of cutting coal were unsatifactory, the supply of labour was inadequate and the miners were neither ambitious nor enterprising and on the otherhand, they were indisciplined and insolent. Moreover, there was no adequate demand even for the small quantity of coal obtained at that time:—use of coal as demostic fuel was practically unknown, industrial demand was also not considerable. Even the Railways, which have been the chief consumers of coal since the inception of this industry had only a mileage of 8707 in 1879 and of 14465 in 1893 and their consumption of coal was only 988908 tons in 1890 (out of which 654829

tons were Indian coal.) The Iron Industry, the next important consumer of coal, was not much in the picture untill the Burrakar Iron Works started in 1874. In 1877 there were only 51 Cotton Mils and 21 Jute Mills and other industries were not yet developed to consume any large quantity of coal.

It was only from the nineties of the last century that a new era of phenomenal increase dawned on this industry. The coal production in India increased from 1.2 million tons in 1883 to 2.8 million tons in 1891-95, 4.8 million tons in 1896-1900. Up to this time only the Raniganj Coalfield was of importance, but the Jaharia Coalfield started coming into prominence and gradually the production from the Jharia Coalfield increased at a rapid rate. The Indian Coal production was 7.6 million tons in 1901-1905, 11.5 million tons in 1906-1910.

Up to the First World War (1914-1918) Coal did not, however, attract much attention. During the War, the demand for Coal increased considerably, and the Indian Coal production went up to about 21 million tons by the year 1919.

Subsequent increase in demand, both internal and external, for Coal, improved transport facilities, better technique and method of production, and labour conditions, led to rapid expansion of this industry, for instance, Cotton Mills increased from 193 in 1900 to 304 in 1935-36; Jute Mills increased from 22 in 1879-80 to 93 in 1926-27 and 104 in 1935-36; the Iron & Steel Industry increased the production of pig iron from 35,500 tons in the begining of the century to 11,75,292 tons in 1930 and 15,41000 tons in 1935-36, that of steel from 139433 tons in 1916-17 to 427035 tons in 1930 and 880000 tons in 1935-36; Railways (the chef consumer of coal) expanded from 14465 miles in 1893 to 40950 miles in 1928-29 and 43118 miles in 1935-36 and their demand for coal increased from 958000 tons in 1893 to 7438969 tons in 1928-29, and 7481873 tons in 1936-37: Coal export rose from an average of 42000 tons during 1891-95 to 881741 tons in 19911-15 and 1224758 tons in 1920.

However, it may be mentioned that during the period 1926 to 1936, though the demand increased, due to cut-throat competition, prices of coal went down considerably, and at times the Coal industry was faced with decline. In 1939, World War II broke out and in 1943 there was acute shortage of Coal. Prices of coal shot up very high and they were fixed in 1944 under Colliery Control Order, and also various laws and orders were promulgated for increasing the earnings of the miners and also for their welfare, with a view to attract labour to the collieries for increasing production.(***)

To summarise, the first published reference to the winning of Coal in this country is in the year 1774 when shallow shafts are reported to have been developed in the Raniganj Field. The venture does not appear to have met with any success and the next serious attempt appears to have been made 40 years later. By the second quarter of the 19th century, a number of seams were opened up in the Raniganj Field. The period 1845-46 is notable for systematic Geological Survey of the field. This was again undertaken during 1858-60. By 1860, nearly 50 collieries were producing 282000 tons of coal per annum. The end of the 19th century saw the Jharia Field gaining in importance. Coal mining in C.P. started in 1862 and in the Rewa States

(*****) †References for data and information :–

(i) Labour in Indian Coal Industry by Dr. B. R. Seth (Pages 1 to 8 of Introduction).

(ii) Indian Economics by Jather & Beri Vol. I (Pages 24–25).

(iii) Report for Working Party for the Coal Industry (1951), (Page 5).

in 1884. The Singareni Field in Hyderabad was discovered in 1872 and was on production in 1887. Development in Upper Assam took place in 1881. By the 20th century the total production was of the order of 6 million tons annually, of which 5 million tons were fron Raniganj, Jharia and Giridih. 1914 saw the opening up of the Bokaro, Pench Valley and Chanda Valley Coalfields and total Indian production was of the order of 16.5 million tons of which Jharia and Raniganj produced 9 million and 6 million tons respectively. Most of it was used by the Railways and industry, for steam raising. The year 1911 is of importance since the Tata Iron Steel Co. was established at Jamshedpur during this period. The years 1914-18 being the period of World War No. I, saw increased activity in every direction and coal production by the end of the War went up to 21 million tons—the shares of Jharia and Raniganj being respectively, 11 and 6½ million tons. Since the year 1920, the Coal mining industry in this country has not been able to have a smooth going.

During the years 1920-26, War time activities declined completely and the output for 1920 fell by about 3 million tons. There was an overall gain during 1924-26, but the coal raisings remained almost the same as at the close of the War. According to the Report of the Indian Coalfields' Committee, 1946, "The reasons for this depression were many. To meet the high post-war demand, a number of workings into seams, which had been ignored as being of no commercial value. had been opened. With the return of normal conditions, these would, in any case, have had to close down. Their existence, and indeed the increase in their number, at the time of the abnormal trade depression of 1920-21, affected the industry very seriously—." But in spite of this decline, prices began to rise steadily in Bengal/Bihar. Between 1920 -23, the prices rose from Rs,6/5/- per ton to Rs. 9/2/- per ton in Bengal and in Bihar from Rs. 4/9/- per on to Rs. 6/15/- per ton. The year 1926 is notable for world wide depression and the prices of coal in Bengal and Bihar were respectively, Rs. 5/4/- and Rs.4/9/- per ton. During the next ten years the downward trend of prices continued till the uneconomic level was reached. The period 1927-30 saw increased production due to increased industrial activity in the country and caputre of export markets. On the other hand, the falling prices of coal encouraged its increased use for power generation. There was another fall in production in 1931 and it became worst in 1933. Frantic efforts were made. to the point of over production with the hope of keeping down the costs. The Pithead prices of Coal in Bengal & Bihar in 1931, were respectively Rs. 2/14/- and Rs. 2/15/- per ton and in 1936, they were Rs. 2/9/- and Rs. 2/10/- respectively. During the year 1937-42 things took normal shape; there was steady increase in industrial demand and consequently, the production increased. By 1942, the prices of Coal in Bengal and Bihar were at about the 1927 level, being Rs.4/- and Rs. 4/8/- per ton respectively. The period between 1942-45 saw extensively increased all round activities due to World War II, and the production surpassed the 1944 level by 3 million tons. The prices rocketted sky high. It became necessary to make every effort to keep up productions and even boost them up and at the same time control the prices. Positive steps in this direction were taken by the Government towards the middle of 1944. Several other helpful measures affecting labour and the management were also taken.

During the subsequent years, the annual output went up still higher and a record figure of more than 34 milion tons was rechead in 1951. Even then our annual coal production is insignificant as compared to those of some of the leading coal producing countries of the World. Comparative figures for production, prices, demand, etc,. are given in the Appendices.

Before passing on to the subject proper, it is desirable to record a few more relevant facts which will help us to uderstand the problem later.

Brief History of Development of the Iron and Steel Insdustry

The Steel Industry practiclly owes its origin to the vision of Sir Jamshedji N. Tata, who founded the Tata Iron & Steel Co. in the year 1907 for manufacture of Iron & Steel. Pig Iron was first produced in December 1911 and Steel in 1913. The break of War in 1914 gave an impetus to the infant industry which by 1916-17 was able to attain full production of its capacity at that time.

At present there are three units of production namely, 1) The Tata Iron and Steel Co. at Jamshedpur, with a capacity of 8,50,000 tons, 2)The Steel Corporation of Bengal, with a capacity of 2,50,000 tons at Burnpur, Asansol, and 3) The Mysore Iron and Steel Works with a capacity of 25,000 tons, at Bhadrabati in Mysore. Of these The Steel Corporation of Bengal started production only in 1940. and the Mysore Iron and Steel Works, although established earlier, has a limited capacity.***

Due to the existence of the Iron & Steel Industry, the production of Pig Iron increased from 35,000 tons in the beginning of the century to 1175292 tons in 1930 and 1541000 tons in 1935-36. The production of steel increased from 139433 tons in 1916-17 to 427035 tons in 1930 and 880000 tons in 1935-36. The production of finished steel increased from 98726 tons to 420654 tons and 677000 tons during the same period.***

The demand for coal by the Steel Works during the period 1946-1950 increased by more than half a million tons. We have now reached a stage when it has become imperative for us as a nation to increase our annual production of Iron & Steel enormously so as to reach a figure of several million tons within as short a period as practicable. This will mean an enormous increase in the consumption of coal for metallurgical purposes over the current figure of about three and half million tons.

Indian Coal Grading

Leaving the Iron & Coal Industry at this stage, we pass on to another important event which took place during the life history of the Coal Industry.

With the cessation of World War I and steady increase in export of Indian Coal, a Coal Grading Board was constituted with a view to ensure a minimum standard and quality of Coal exported. In 1926, it issued a regulation classfying commercial grades of Indian Coals based on their contents of ash and moisture and calorific value as shown in the table in the Appendices.

Subsequently, the classification was extended to cover Coals in general and the above scheme was modified to make it easily applicable to Coals not intended for export. Later, in 1944, the prices for various grades were fixed. This modified scheme is known as the Indian Coal Commissionner's Grading and is shown in the table in the appendices, as they stand at

(***) Fiscal Commiissicn 1949-50, Page 58–59.

(***) Labour in the Indian Coal Industry by Dr. B. R. Seth, (Page 7-8 Introduction).

present. These important measures taken, although not quite scientific and rational in basis, proved quite beneficial to a degree and even helpful to the industry and consumers within the limits of the scope.

Coal for domestic consumption:

Before leaving this section of my talk, the picture will not be complete unless a brief reference is made to the position in this country, regarding our consumption of coal for domestic purposes. Compared to the size of the country, the consumption is surprisingly very low. The "World Coal Mining Industry' 1938, gives the follwing comparative figures:

		MillionTons
U.S.A.	...	103
Germany	...	42
Great Britain	...	36
South Africa	...	1.61
Italy	...	0.58
Spain	...	0.18

Although Indian consumption is described as negligible, we know that it is considerably more than one million tons per annum. According to Indian Coalfields Committee (1946) the total quantity of Coal used for domestic purposes is about 2.3 million tons per annum. The bulk of this consumption is confined to Bengal and Bihar, and includes about 8,00,000 tons of coal used by the colliery labour.

Present Trend and Future Outlook

With this historical background before us, we may now proceed to examine the subsequent developments, our present difficulties and the future outlook. The World War II and its after effects, inflation within the country, labour unrest, rapid developments arising out of successive legislative measures and enactments, etc., have all combined to shoot up the price of coal enormously. Although the prices are fixed, they are not quite properly or scientifically related to the quality, which is more often indifferent than uniform. There is no incentive or initiative left to the industry to make forward progress. Confusion and uncertainty prevails everywhere. There is an acute scarcity of wagon supply and it has become almost chronic. One class of producers find themselves placed at a disadvantage with respect to others. A large number of mines working what is commonly known as low grade coal, which could come into existence only due to urgent demands, and in many cases managed by 'Gold Diggers' who were attracted to this field more by the prospect of making quick millions and possibly never thought of sticking to this profession, find themselves more or less trapped. It is natural that they should clamour for right to exist and insist on the use of such coal and even have it thrust on consumers, though in fact, it is no better than drug in the market. Indeed, they go so far as to suggest that overseas countries should be made to accept it against their import and their claim regarding the advantages and efficiency in the use of this class of coal makes one wonder whether it will not be better still to use muck instead of any coal at all. This movement, helped by the hue and cry raised mainly by the Iron & Steel interests, and the submission of reports by the Enquiry Committees officially appointed from time to time led the Central Government to the conclusion that something decisive had got to be done

and the resources of coal suitable for metallurgical purposes should be conserved without any further delay. Their hands were ultimately forced to be directed towards adoption of a negative policy of very doubtful value by restricting the output of coking coal and reducing it drastically within the next 5 years, to the extent of 40% of normal rating. It is not for us Engineers, to criticise the Government but to help them with constructive suggestions and sound advice, so that, any measure that may be taken by the national Government, is in true interest of the country ensuring utilisation of coal to the fullest advantage by every class of consumers, since true economy lies in mining well and using well.

Indian Coal Reserves and Future Demands

We have from the report of the Working Party for the Coal Industry, 1951, (Page 17), that the reserve of good quality metallurgical coal in virgin areas and working collieries, if methods of Stowing, beneficiation and blending are resorted to, may be estimated as 2000 million tons. Of this total quantity, about 750 million tons or a little more than one third, are in working collieries, On the other hand, possibilities of discovering more deposits of metallurgical coal in future can never be ruled out. The discovery of the Talcher Coalfield in this country in not very distant past, and the concealed coal fields of Kent and Belgium, will strongly support this view.

From the same report we learn that our reserve of non-coking coal is fairly vast and about 40,000 million tons based on information available so far.

A reference to Appendix 'C' will give an idea of demand, allocation and despatches of coal for the year 1950, with respect to some of the more important consumers. Appendix 'D' gives an idea of industrial demand, Provincewise for the same year.

According to the estimates of the Indian Coalfields' Committee, 1946 India's future requirements in 1956, will be 39 million tons and a progressive increase in supply of Coal at the rate of $1\frac{1}{2}$ million tons a year is recommended.

It is noteworthy that the Railways are the most important consumer of coal and their demand is nearly 1/3rd (nearly 11 and a half million tons) of our total annual production of coal.

The next important consumer is the Iron & Steel Industry, the consumption being little more than 1/3rd of the Railways' requirement or somewhere about three and a half million tons. The next two important consumers worth mentioning are the Cotton Mills with an annual demand of nearly 2 million tons and the Cement Factories with an annual dmand of little over 1 million tons. The demand due to other important industries such as Jute, Engineering Paper, and Coke Ovens, is near about half a million tons per annum. The demand due to the Brick manufacturing industry, however, is nearly as much as that of the Iron & Steel Industry, being over 3 million tons.

Considering provincewise, the most important consumers are West Bengal and Bihar, the demands being respectively nearly six and a half million tons and four and a half million tons per annum. The next two important coal consuming Provinces are Bombay and the Punjab with a demand of slightly over 2 million tons. The demands due to Delhi and Madhya Pradesh is in each case slightly over 3/4th of a million tons. The remaining provinces require far less quantity of coal annually.

By far the major portion of our production is confined to the Jharia and Raniganj Coalfields which together produce more than 78% of our coal.

Most of the good quality coking coal is obtained from the Jharia field and its production constitutes nearly 75% of the total for this field. The present figures is near about 8 million tons per annum.

The Pegging Measure:

The Central Government has been made to accept the view that since the current demand for good quality coal for metallurgical purposes does not exceed 4 million tons per annum and its output is nearly double of this figures, so much of this coal is being allowed for other purposes, and since the total reserve of such coal is only 2000 million tons, such indulgence in its use is merc frittering away of the resources of the country. It has, therefore, been proposed in all seriousness to drastically reduce this figure till the 5.5. million tons per annum level is reached within the next 5 years or so. This virtually means a reduction of nearly 40% in output. The fallacy of such an unwise policy, whi h is considered a negative policy by many, will be apperent if the position is considered with vision and independent outlook.

At the present rate of consumption of say 4 million tons per annum for Iron & Steel manufacture, the coal reserve should last for another 500 years. Suppossing the consumption goes upto 10 million tons per annum by the end of the next few years due to setting up of additional Iron & Steel Plant, the coal reserves even then should last for another 200 years. No Engineer or Metallurgist will agree that the methods of manufacturing Iron & Steel will not change during the next two centuries, and it will all along be dependent upon the use of Coke from coking coal. It is true that the Iron & Steel Industry has been very backward in the matter of evolving new process for smelting Iron without depending upon adequate supplies of coking coal. It is also true that in this respect it is not in the same happy position as the Petroleum, Rubber, or Chemicals & Fertilizers Industry, although they started much latter. In this modern age any of these industries seems to be able to produce things from raw materials which one could never think of using in the past. There is no reason why the Iron industry should not be able to take an example from leaders in industry and overcome its difficulty with a little more foresight, effort, and perseverance. Already there are indications that the Iron industry is going to be independent of coking coal as one of the raw materials. Considerable advances have been made in this direction in Germany, Sweden, and other leading countries. It is time that this industry in our country woke up and tried to help itself instead of clamouring for help at the cost of others. There are only 2 or 3 Iron & Steel producing concerns in the country enjoying monopoly so to say and it is surprising that they are incapable of looking ahead and working for the day when there will be no more coking coal available to meet their demand.

We may now try to consider what the Pegging policy will mean if enforced and what will be its ultimate effect on the Coal Mining Industry. For benefit of those not conversant with coal mining operation, I may mention that the method of underground mining generally pursued in this country, is the so-called 'Board & Pillar' method which means that after reaching the coal seam below surface through a shaft, the ground is opened up by driving tunnels or galleries in two directions at right angles so as to block out the seam into hollow spaces with pillars supporting the roof and the over burden. This is really the first stage in winning coal and the percentage of coal removed in course of driving the gallery is really small compared to what will be obtained latter. As the workings advance fairly from the shaft bottom, it becomes necessary to remove these pillars and extract the coal so that an increasing output may be obtained and the costs may be

kept down within reasonable limits. The extraction of the pillars is hazardous and dangerous and the loss of coal during such operation is variable; I need not go into the reasons and causes in this connection. As Engineers, you will readily realise that the size of the pillars has to be adequate enough to be able to carry the weight of the overburden as the pillar of coal is not the same and as stable as a pillar of masonry or concrete, it deteriorates due to continuous atmospheric action and the action of the forces affecting underground stability. Its size thus gets gradually diminished due to spalling, splitting, etc., and the dangers due to the size reduction increase with age. That is why, it is considered very unwise to leave the pillars unextracted for long.

The class of coal whose output is proposed to be drastically reduced, is to be found in mines which are in an advanced stage of development and mostly standing on pillars waiting to be extracted. These mines produce near about 8 million tons of coal annually or about 25% of our annual production and these also happen to produce the best quality of coal available within the country. Restriction in output in the interest of the Iron & Steel Industry means discrimination in its favour and all other industries are going to be deprived of this source of supply. The Railways are dependent largely on this class of coal because of its high calorific value and fairly low ash content. Very strong attempts have been made by interested people to make out a case in favour of using poor grade coal by the Railways, but no Fuel Engineer or Technician can ever endorse this ill-advised suggestion. Apart from all other considerations, it will be astounding to find what an enormous amount of inert matter will have to be hauled by the Railways if low grade fuel is used. This will virtually mean so much useful work wasted. Can it be allowed to be done unless suitable fuel for the Railways is found?

Earlier, we propounded the thesis that true coservation lies in efficient extraction and utilisation and not in restricted mining and use. Such a propositon connotes elimination of all sorts of wastages. If the principle is accepted it has got to be ensured that there is no avoidable wastage at any stage, either in course of mining or during utilisation Since the pegging is conducive to increased loss during mining and is very harmful in effect, it is of no use and cannot be supported;—it will defeat the very object in view. Even if enforced due to wrong advice and misguidance, it will have to be called back sooner or later when reality asserts itself to drive out ignorance and dream. On the other hand, the wisdom of adoption of necessary measures to ensure extraction and use to the maximum possible extent is unquestionable and can never be challenged. Today, we are faced with an awkward situation with respect to future supplies of only one class of coal, sooner or later we may have to face a similar problem with respect to the supply of every class of coal. The steps we may decide to take at the moment, in order that they may be lasting in effect and enduring, should be applicable equally well at all times, to every class of coal. The most rational methods of proved value and efficiently practicable in application, available to us, are stowing and beneficiation.

Sand Stowing

An Engineer need not be told that if a roof support carrying the weight of the roof has to be removed, the latter must be otherwise supported properly before any such attempt can be made. Failing that, the roof itself will come down. This is generally what happens in a coal mine when the supporting pillars are removed. Under the circumstances, much of the coal in the pillar

so extracted have to be left behind for fear of loss of human lives and because of various other practical difficulties. However, much of this coal lost in course of such operation can be avoided if the roof is properly supported by packing before starting the extraction. Indeed, the extraction can be one hundred per cent under favourable conditions. Such a method, in which packs of sand are used, is available to Mining Engineers;—it is commonly known as Sand Stowing. Although it originated in Western Countries, it has been in use in this country for a good many years and is being used in mines whose management has vision and resources to afford it, with considerable success. Wherever adopted, it has proved to be efficient, beneficial and helpful —its adoption has resulted in the saving of a considerable amount of coal which would have been lost otherwise. There is no two opinions regarding advisability of universal application of this method, for underground mining in this country if necessary funds and materials are available. The national Government is well advised to concentrate their energy and resources in this direction. Measures taken in this connection will be definitely positive measures and the results are sure to be handsome and surprising.

The method is essentially one of carrying a mixture of sand and water from surface to the site, underground to be packed, through pipe lines and ultimately filling up the vacant space. The water drained out of the sand pack so deposited is ultimately removed by pumping. Thus the arrangement for the purpose requires surface installations for receiving sand from outside, its storage and handling, suitable device for mixing with water and necessary pipe lines for carrying the mixture from the surface, down the saft and ultimately to the site. Besides, an installation for underground pumping and pipe lines for returning the water to the surface are essential. Although this method has been in use for some time, it is essentially empirical in its application and much still remain to be known about its fundamental aspect. The cost is very high because of the size of the installation required; abnormally thick cast Iron Pipes are generally used as transimission lines and the wear and tear is very heavy. Installation of such pipe lines in deep shafts and their replacement as and when necessary are extremely difficult. The working is subject to involuntary interruptions due to blockages in the pipe lines. In order to save the cost of pumping water, the water/sand ratio is kept down to the minimum. From the information available, it seams, the tendency to restrict the use of water is based on wrongly conceived ideas. This results in an inefficient use of the transport system which is made to do far less work than it can actually do, and false economy in the end. It may be, most of the troubles encountered in this connection, are attributable to this cause.

As the method in its fundamental aspect, is essentially one of handling and transport of matrials, it provides excellent scope for Engineers who may feel so inclined, to carry out researches of both fundamental and applied nature, to collect useful information so that it can be vastly improved upon and the working expenses reduced considerably. When this is done, its scope of application may be expected to be wide and within the reach of many more collieries.

Regarding the transport of sand/water mixture through pipe lines, much remain to be known about the nature of the flow itself under the condition available. Is it a case of simple transport of sand by water; if so, is the flow viscous or turbulent or both, depending upon the section of the pipe line considered. What is the critical velocity and corresponding Reynold's number for various mixtures of sand and water and what are the absolute

viscosities and densities of such mixtures Is there any reason to believe that it is a case of transport of solids in a fluidised state, if not, will it be for the better to create conditions favouring this kind of flow. From evidences available, it appears that quite a large portion of the upper section of the pipe line in the shaft is not doing its full share of work and running partially empty all the time. In other words, the surface portion of the pipe line is unable to keep pace with the supply as soon as the materials commence their freefall through vertical section. Is this condition conducive to economy; does it encourage faster wear and tear. Can this deficiency be over come by varying the section of the pipe line, scientifically according to requirement, instead of using uniform section through out. I am sure, there is an excellent scope for research and the field is vast. It should be part of our Central Government's policy towards coal conservation to encourage very active research in this direction and provide adequate funds for the purpose. Such researches cannot be undertaken by individuals or individual concerns.

Introduction of sand stowing on an extensive scale together with systematic working of mines and elimination of small properties are the surest means of increasing the quantity of coal recoverable. It is surprising what an enormous quantity of coal can be lost during mining due to irregular working of a colliery and small size of the property. It may be as much as 50% of the deposit itself. The pegging measure proposed will only encourage irregular working. Regarding uneconomy and disadvantages of working small properties, I may only point out that since for obvious reasons every mine is required to leave an adequate thickness of coal as untouched barriers, at its boundary, for its own safety as well as for safety of the adjoining mines, all this will be lost by the time the mine is exhausted and if the property is small, its proportion to the whole can be considerable.

Benification of Coal.

Having indicated how the recoverable quantity of coal can be increased by adopting suitable positive measures to prevent loss and wastage in mining, we may now proceed to examine how increased supplies of good quality coal can be ensured;—by good quality coal, I mean, coal with low ash content, high calorific value and for metallurgical purposes, with good coking property. Excellent methods of benefication of proved efficiency are avilable for the purpose. As the name itself suggests, by this method the coal substance can be made available in a more concentrated form out of an indifferet supply It is expensive, but nevertheless, since the value is increased, there is a reasonable possibility of fair return.

Coal as mined is not pure coal substance. It has finely dissiminated mineral matters mixed up with it, constituting what is known as ash or intrinsic ash. Besides, the deposit may have intercalated bands of stone and shale which have to be mined along with the coal and cannot be removed readily after mining, except by special methods,—the so-called methods of cleaning and washing. Lastly, a certain amount of stone and dirt from extraneous sources gets mixed up with the coal during mining, and they can be removed only up to a degree. All these combine together to increase the inert mineral matter in coal as mined. Under the circumstances, the quality of coal reaching the consumers is in many cases poor and indifferent, although, they have to pay just the same freight and handling charges, etc., on this unwanted portion of coal. We have large deposits of coal with good coking property, but they are considered unsuitable for metallurgical and other purposes such

as gassification, because of their comparatively high ash contant. Adequate supply of good quality coal to the Railways is threatened to be cut off because a large portion of the present supply happens to be coking coal. Consumers at a considerable distance from the source of supply are at great disadvantage if required to use inferior quality coal with high ash content. On the other hand, our reserve of good quality coal is already depleted and will continue to do so in future. Under the circumstances, it is imperative that some thing has got to be done to keep up the quality. Our export trade in coal is doomed if we fail to ensure it.

The methods of beneficiation are as a rule based on the difference in specific gravity between the pure or comparatively pure coal substance and the dirt which may be purely stone, shale or shaly coal. The higher the difference and the more readily the two detach from each other due to breakage during mining and subsequent handling, the easier and more efficient is their separation and the operation of cleaning coal. Due to the inherent difference in resistance to breakage between the two, size reduction is conducive to liberation of dirt held in the coal substance and the degree of size reduction required, depends upon the character of the coal itself and the extent of benefication aimed at. In any case it has to be progressive and must bear a close relation to the ultimate net gain. Theoretically, it is possible to get almost pure coal substance by fine grinding and subsequent cleaning. There are many types of Indian Coals which cannot be cleaned properly without resorting to extreme size reduction. It is considered uneconomic to clean such coal. It is also often said that most of our coals cannot be cleaned to the desired extent without much loss of coal in form of middlings (mixture of coal and dirt) and discards. While such views represent mere ways of looking at things and may hold the field so long as there is no well thought out rational policy regarding use of coal from fundamental point of view they are totally wrong. If coal has to be used well, if it has to be utilised to the fullest extent with reasonable efficiency, there should be well defined policy for the purpose, so that nothing is wasted,—at least to the avoidable extent. Under such condition the problem of utilisation of middlings and discards will not arise, and the methods of beneficiation can be harnessed to the fullest possible extent.

The wet methods of cleaning are more extensively used and they have proved their worth beyond doubt. They may be based on the principle of hindred settling as in the case of Jigs and Trough washers or on the use of heavy medium in which comparatively pure coal which is lighter in specific gravity is made to float. Lately, at least two cleaning plants working on the principle of heavy medium separation have been set up in this country and the idea seems to be gaining that this is the only suitable method available. It may be pointed out, this method may prove to be too expensive unless a very high throughput is aimed at and maintained. Otherwise, the older methods of jigging or trough washing are likely to prove more economic for smaller concerns. Generally speaking, each case requires individual examination before deciding upon the method and type of plant to be used. In many cases it may be found advisable to use a combintion of methods and plants. In any case the plant installation required is quite expensive and the working cost high,— more so because a very large part of it has to be imported. In fact, we are at a disadvantage in this respect, and our Engineers can step in to remove it by undertaking to design and construct these items in this country. There is no reason why this cannot be done.

The main difficulty preventing introduction of methods of beneficiation on a wide scale is very grave doubt regarding recovery of the cost of preparation and cleaning and a reasonable return on the capital to be invested—if it is at all available. It seems there are few mines that can afford to lay out the amount required. Besides, the question of economic disposal of the middlings is there; however, for reasons already explained such an outlook cannot be encouraged. Further, the existing price structure fails to encourage the producer to produce and the consumer to use cleaner coal. Such incentive can only be created if the price is related to the utilisable value contained in coal, on proper basis. This requirement is very important not only for internal consumption of coal but also for export purposes.

Cleaning Plants are highly mechanised and expensive. They cannot be worked economically below the minimum rated throughput which is generally high. It is essential that they should be worked regularly without prolonged interruptions. To ensure this it is imperative that the finished products should be simultaneously removed and sent away so that there may be no involuntary stoppage due to congestion in the plant. Considering the acute position regarding wagon supplies and Railway movement in the country, it seems, little headway can be made regarding installation of cleaning plants on an extensive scale till the distribution and transport system is re-organised and brought up to present and future requirements.

The pegging policy as proposed, is sure to have an adverse effect on installation of such plants in future. In its present form it restricts the production of what is called good quality coking coal with an ash content up to 17%. There are extensive deposits of good coking coal which is considered unsuitable for metallurgical purposes because of its high ash content. Nevertheless, this class of coal with an ash content above 17%, if properly beneficiated, can be used as good quality coking coal for metallurgical purposes. If there is danger of coming within the mischief of the pegging policy as the result of bringing down its ash content by cleaning, there will be little inclination to try to beneficate such coal; such efforts may even prove suicidal for a mine bold enough to venture. It seems, the pegging policy will virtually mean a primium for high ash content of this class of coal. In our own interest, it is very desirable that preparation and cleaning of Coal before marketing should be undertken at a very early date by as many collieries as practicable at this stage; although, the aim should be for all collieries to fall in line as soon as conditions permit. The impediments in the way have got to be removed by the Central Government and the Railways before tangible efforts on a scale conceived herein, can be made. Our Engineers and Technicians have got to play no small part in this connection. All their technical ability, ingenuity and flare for invention are called for.

Future outlook and Policy.

We have seen earlier that although coal mining actually started in this country as early as 1872, the progress has been very slow. From an average annual output of about one million tons in 1880, it has taken more than 70 years to reach the present anual total of more than 34 million tons; even then, our position as a coal producing nation is very low down the list. This is also a criterion to our industrial status in the international sphere. Our industrial development has been indeed very slow and every noticeable increase in the annual output and consumption of coal can be more or less correlated with increased industrial activity and expansion by the Railways. The two World Wars, though otherwise unfortunate, gave tremendous but

spasmodic impetus to industrial development and productions shot up abnormally in consequence.

The price structure of coal has always been closely associated with the foot falls of the coal industry and it has yet to play a far more important part if this industry is to develop on sound lines and attain the full stature it is capable of, within the minimum period in future. Since the known reserves of our best quality coal are much depleted and we must of necessity mine and use increasing quantities of poorer grade coal, preparation before marketing is imparative. Past misconceived idea of our advantageous position because of our abundance of cheap raw materials and labour is exploded and the mischief it has done to our industrial progress should be aparent. No nation can be tempted to exert much towards their proper, scientific utilisation if two of the most important factors affecting industrial development, such as labour and fuel—the universal means of getting energy are cheap and plenty. Such a position can never create any incentive to do things to increase efficiency and production, quality control and invention. If the extra gain is not commensurate with the result aimed at, it is but human and natural to lean towards the *status quo.* It seems, the inflationary period we are passing through is a boon in disguise and if the coal prices are not allowed to fall below a predetermined limit, not only the coal industry but also all those depending upon coal as one of the main raw materials, can look forward to sustained forward march and take necessary steps with full confidence.

In the opening remarks it was pointed out that Coal is the material source of the energy of a country—the universal aid the factor in everything we do. Engineers require coal to liberate energy in form of heat and once it is available, it can be directed to material use ad infinitum, since energy is indestructible, but can be readily transformed from one form to aother. Today, the question is not how and how much of coal can be changed to heat energy but, how to hold and utilise it properly. To a properly trained Fuel Engineer and Technician no quality of coal is worthless or unutilisable, so long as he can apply proper methods and the economic consideratios are not beyond his control. As early as the year 1924 or thereabout, some Belgian Coal Mines found it possible to utilise Washery sludge containing about 50% ash for steam raising and power generation. The apprehensions regarding disposal of high ash middling from cleaning plants do not really exist if they are put to proper use. They may not suit locomotive or marine or certain stationary land boiler conditions because, in such cases, a much increased rates of firing called for, to keep up generation of the required amount of heat is not possible. But with a stationary land boiler specially designed for the purpose, no such difficulty will be encountered. Again, economic considerations, favour location of such boilers for steam generation more near the source of supply of the fuel than away from it. In fact it is economically impossible to utilise such a fuel beyond a certain distance from the source and it will be foolish to attempt it unless there are special considerations.

By far the largest quantity of coal is used for steam raising and it will continue to be so for a long time ahead till enough energy from other sources can be brought under the control of man to meet all his requirements. Hydro-electricity is still a doubtful proposition in the country. Our dependence on external sources for necessary plant, materials and know hows makes it too expensive for us. Recent failures in Bombay and Madras have shaken our faith regarding the continuity of supply. No doubt, it was found wise by the D.V.C. to set up a 'Thermal Power Station at Bokaro, to ensure continuity of

supply in case its hydroelectric power stations fail partially or even completely due to deficiency in the supply of water. So far as the use of wind power or solar energy is concerned, the position in the country is not worth mentioning. Lately, a tall claim has been made regarding the use of solar energy, in replacement of domestic fuel, but it is to be feared, at this stage it is no more than mere paper propaganda.

Thus whether for steam raising and power generation or for mere furnace heating and other purposes, coal is the principal source of heat energy. The subject of power production from coal is so vast that it will be futile to try to dilate on it within the short compass of this paper. We are painfully aware that even under the best conditions, we are unable to utilise more than 30% of the heat energy put in, inform of coal, to do useful mechanical work. In the case of steam locomotives, no more than 6-7% of the energy is available at the draw bar to do useful work—a very low figure indeed. On the other hand, much of the energy wasted, can be utilised for other purposes, such as space heating and processing. Such an arrangement, of course, will not help us to get more mechanical work done, but it will have distinctly favourable economic effect on the cost of power generation and consequently its use on a much wider scale. It is common practice with modern factories where the conditions exist, to integrate the use of heat energy in coal to this effect.

Our Railways consume about one third of our annual production of coal and it is estimated, more than 25% of the wagons available has to be used for its transport. In number, it is possibly about one third the total allotted annually, for transport of coal. The wagon position, whether it is for transport of coal or for other goods, is already very acute. As the result of the Pegging policy, if the Railways are compelled to use increasing quantities of inferior quality of coal with high ash content and low calorific value, it will virtually mean withdrawl of more wagons for their own use. In the same way wagon requirement of public consumers are sure to increase, and the longer the haul the more the wagon requirement. Besides, transporting increased quantity of inferior coal amounts to hauling more and more unwanted inert mineral matter on which freight has to be paid. This is sheer waste in every respect. Our rational policy regarding utilisation our coal resources should, therefore, aim at:

1) Use of only low ash coal with high calorific value (concentrated calories so to say), whenever it has to be consumed beyond a certain distance from the source and for export purpose.

2) Beneficiation of coal to the maximum possible extent to meet the first requirement. Even coal hitherto considered good quality may not be left out of the scope.

3) Setting up of Super Power Stations throughout the Coalfields wherever conditions permit and preferably not far from the Railways to utilise washery sludge and part of the middlings from Coal Cleaning Plant most conveniently placed.

4) Connecting up such power stations in form of a grid system to supply power for traction to the Railways and also make power available over wide areas in replacement of Coal to the maximum possible extent.

5) Integrating such power stations with processing and other industries requring heat energy, so that the amount of heat wasted in power generation and not utilised, can be made use of, at least partly.

Such industries will have to be encouraged and set up if they do not exist.

6) Setting up low temperature carbonisation plants to carbonise all the middlings available after meeting the requirements of the power stations with the waste heat and steam available, and the heat in the gas produced for ultimate distribution as domestic fuel, for use in the power station itself or even for gas manufacture and synthesis, at site. Manufacture of coal chemicals will naturally be integrated with the scheme and the low temperature tar produced (the quantity will be considerable), can be made into excellent oil fuel after processing or utilised for manufacture of synthetic motor spirit.

7) Elimination of steam locomotives for traction as far as possible and concentration on electric traction using thermal or hydro-electric power, according to the area and location, and also on, Diesel, Diesel/Electric traction where electric power may not be available; oil fuel obtained from low temperature carbonisation of the middlings will meet a large part of this demand.

8) Utilisation of all surplus gas available for Coke Ovens and coal tar and tar oils, for fuel purposes. It is astonishing that in spite of acute shortage of imported fuel oil, Coal tar distilleries are compelled to reduce output because of congestion in the plants due to accumulation of undisposed tar oils.

9) Utilisation of Coke Breeze for gasification and steam raising on a much wider scale. Huge Coke Breeze dumps are to be found near about each Coke Plant. Production of a certain percentage of coke breeze in manufacturing Hard Coke is unavoidable. In Western Countries, it is not allowed to accumulate and used up as it is not an inferior fuel. An enormous inrease in the price of coal during the past years, and very low price of coke breeze fixed by the Coal Commissioner, gave incentive to its use and at least one firm in Calcutta was progressive and bold enough to make use of it for gasification and furnace heating, in complete replacement o raw coal. Since then its use has been increasing steadily, but there is scope for further increase.

I have tried to present a picture of the vision as it appears before my eyes, in bare outline. If I have failed in any respect, if I appear to have overstated things, I hope to be excused. It is possible, I may have allowed myself to be carried away by the vision. Nevertheless, I live for the day to see coal utilised as completely as the ingenuity, vision and technique of man will permit. If I have been able to impress upon you that it is the energy contained in Coal in form of heat units, we are primarily interested in and not the coal itself, irrespective of whether it is *X*, *Y*, or *Z* class, I should consider myself amply rewarded. It will be wrong to imagine that all this will mean decreased consumption of coal. Actually, it will lead to a considerably increased consumption with an all-round benefit.

I thank you again for your extreme patience.

"Vande Mataram"

Appendix A

Statement showing output of Coal in Indian Provinces and States—1920-1945

Output and Average Prices of Coal in British Indian Provinces and States.

Year.	Total Annual Output. Tons.	Average Prices.
1920	17,962,214	Rs. 5/3/–
1921	19,302,647	6/12/–
1922	19,110,814	7/11/–
1923	19,655,612	7/7/–
1924	21,174,129	7/1/–
1925	20,904,352	6/1/–
1926	20,999,167	4/13/–
1927	22,082,336	4/5/–
1928	22,542,872	3/15/–
1929	23,418,734	3/13/–
1930	23,803,148	3/14/–
1931	21,716,435	3/13/–
1932	20,153,387	3/6/–
1933	19,789,163	3/2/–
1934	22,157,447	2/14/–
1935	23,016,695	2/13/–
1936	22,610,821	2/12/–
1937	25,136,386	3/2/–
1938	28,342,906	3/12/–
1939	27,769,112	3/9/–
1940	29,388,494	3/9/–
1941	29,463,742	3/11/–
1942	29,433,253	4/7/–
1943	25,368,879	6/10/–
1944	25,965,556	Prices as fixed by the Coal Commissioner.
1945	28,972,548	

Appendix B.

World Coal Production in 1951 in some of the leading coal producing countries and India

(In 000 Metric Tons.).

America	5,18,819
China	41,000
India	34,307
Great Britain	2,11,900
Germany	1,18,925
Poland	81,700
France	52,967
Russia	2,85,000

APPENDIX C.

Statement showing Demand, Allocation and Despatch for the year—1950

OUTPUT FOR THE YEAR 1950—32,260,743 TONS.
(Only the more important figures are given.)

ass.	Demand.	Allocation.	Despatch.
XX/BNK (Bunker) ..	680,396	680,096	429,937
XX/EXP (Export) ..	1,342,618	1,439,585	1,251,111
LOCO	11,338,164	11,218,746	10,030,438
ELC (Electricity)	2,336,800	2,321,752	2,249,088
STL (Steel Cos.)	4,028,000	4,000,800	3,623,427
CMT (Cement)	1,051,600	1,047,064	923,817
COT (Cotton)	1,919,200	1,862,900	1,665,008
JUT (Jute)	728,880	724,021	577,412
ENG (Engineering) ..	460,617	458,093	364,483
PPR (Paper)	474,432	470,642	456,696
COK (Coke Ovens)	494,052	490,788	373,455
BRK (Brick Burning) ..	3,152,336	2,996,930	1,718,679

The total demand was 34,742,426 tons against which 34,369,888 tons were allocated and 28,236,507 tons despatched.

APPENDIX D.

Statement showing average Annual Industrial Demand of States for Coal (1950)

Names of States.	Demand in tons.
Assam	151,475
Bihar	4,461,642
Bombay	2,076,083
West Bengal	6,413,748
Madhya Pradesh	814,915
Madras	1,009,102
Orissa	174,922
Punjab	2,188,410
Madhya Bharat	333,892
Pepsu	228,581
Rajasthan	510,556
Saurashtra	291,688
Travancore & Cochin ..	26,845
Hyderabad	85,428
Kashmir	9,528
Mysore	122,676
Vindhya Pradesh	16,926
Ajmer	18,105
Bhopal	29,848
Delhi	839,845
Himachal Pradesh	3,234
Kutch	1,242
Tripura	1,653
TOTAL ..	20,878,482

The total figure given above does not include the following:–

1. Export ..	1,365,285	
2. Bunker ..	680,096	
3. Railways ..	11,142,000	
4. Ginning ..	150,000	
5. Defence ..	57,797	
		13,395,078
TOTAL ..		34,273,560
Pakistan's current demand ..		1,827,000
GRAND TOTAL ..		36,100,560

Appendix E.

Export. — Indian Coal grading board classification.

Low Volatile Coal (Mainly Seams of the Barakar Measures).

Grade.	Ash Per Cent.	Minimum Calorific Value. B. T. U. per lb.	Remarks.
Selected	Up to 13	12,600	The moisture in all cases must not exceed 2 per cent.
No. 1.	13 to 15	11,700	
No. 2.	15 to 18	10,800	
	over 18	under 10,800	

High Volatile Coal (Mainly Seams of the Raniganj Measures).

Grade.	Ash per cent.	Moisture per cent.	Minimum Calorific Value. B. T. U. per lb.
Selected	Up to 11	under 6	12,240
No. 1	11 to 13	under 9	11,340
No. 2	13 to 16	under 10	10,800
No. 3	inferior to No. 2.		under 10,800

Appendix F.

Not Export—Coal Commissioner's Grading.

For Coals of the Raniganj Measures.

Grade.	Ash plus Moisture per cent.	Remarks.
Selected A	Under 17.5	Calorific values are not required.
Selected B	17.5 to 19.0	
No. 1	19.0 to 24.0	

For Coals of other Seams.

Grade.	Ash per cent.	Remarks.
Selected A	Under 15	The moisture shall not exceed 2 per cent as delivered. Calorific values are not required.
Selected B	15 to 17	
Grade I	17 to 20	
Grade II	20 to 24	
Grade IIIA	24 to 28	
Grade IIIB	28 to 35	

Appendix G.

Price list of various Grades (Pit Head).

Jharia and Raniganj Fields.

Grade of Coal.	Maximum Ash % (Jharia Coals).	Minimum Ash & Moisture % (Raniganj Measures.)	Price. Slack & Dust. Rs. As. P.	Price. Steam, Nuts, etc. Rs. As. P.
Sel. A.	15	17.5	15 3 0	16 4 0
Sel. B.	17	19	14 3 0	15 4 0
Gd. I.	20	24	13 5 0	14 6 0
Gd. II.	24	..	12 15 0	14 0 0
Gd. IIIA.	28	..	11 12 0	12 12 0
Gd. IIIB.	35	..	10 9 0	11 9 0

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5th	,,	1918,	Lahore	--	--	--	5	10	0
6th	,,	1919,	Bombay	--	--	--	3	0	0
7th	,,	1920,	Nagpur	--	--	--	3	12	0
8th	,,	1921,	Calcutta	--	--	--	4	14	0
9th	,,	1922,	Madras	--	--	--	5	4	0
10th	,,	1923,	Lucknow	--	--	--	7	8	0
11th	,,	1924,	Bangalore	--	--	--	6	12	0
12th	,,	1925,	Benares	--	--	--	9	0	0
13th	,,	1926,	Bombay	--	--	--	12	6	0
14th	,,	1927,	Lahore	--	--	--	9	12	0
15th	,,	1928,	Calcutta	--	--	--	12	12	0
16th	,,	1929,	Madras	--	--	--	12	0	0
17th	,,	1930,	Allahabad	--	--	--	15	0	0
18th	,,	1931,	Nagpur	--	--	--	13	14	0
19th	,,	1932,	Bangalore	--	--	--	18	12	0
20th	,,	1933,	Patna	--	--	--	17	4	0
21st	,,	1934,	Bombay	--	--	--	12	12	0
22nd	,,	1935,	Calcutta	--	--	--	15	0	0
23rd	,,	1936,	Indore	--	--	--	18	0	0
24th	,,	1937,	Hyderabad	--	--	--	16	8	0
25th	,,	1938,	Calcutta	--	--	--	30	0	0
26th	,,	1939,	Lahore	--	--	--	20	0	0
27th	,,	1940,	Madras	--	--	--	27	6	0
28th	,,	1941,	Benares	--	--	--	30	4	0
29th	,,	1942,	Baroda	--	--	--	25	8	0
30th	,,	1943,	Calcutta	--	--	--	19	8	0
31st	,,	1944,	Delhi	--	--	--	18	0	0
32nd	,,	1945,	Nagpur	--	--	--	18	4	0
33rd	,,	1946,	Bangalore	--	--	--	21	4	0
34th	,,	1947,	Delhi	--	--	--	23	2	0
35th	,,	1948,	Patna	--	--	--	23	0	0
36th	,,	1949,	Allahabad	--	--	--	21	12	0
37th	,,	1950,	Poona	--	--	--	23	12	0
38th	,,	1951,	Bangalore	--	--	--	27	12	0
39th	,,	1952,	Calcutta	--	--	--	32	6	0

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